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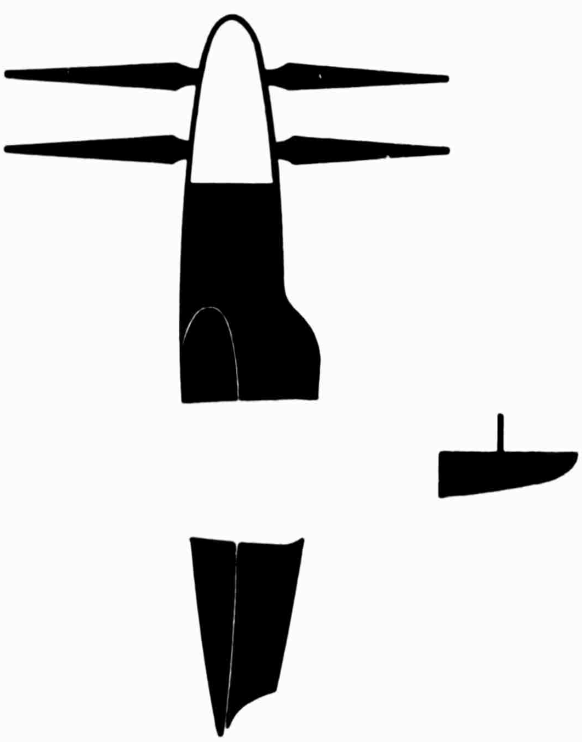

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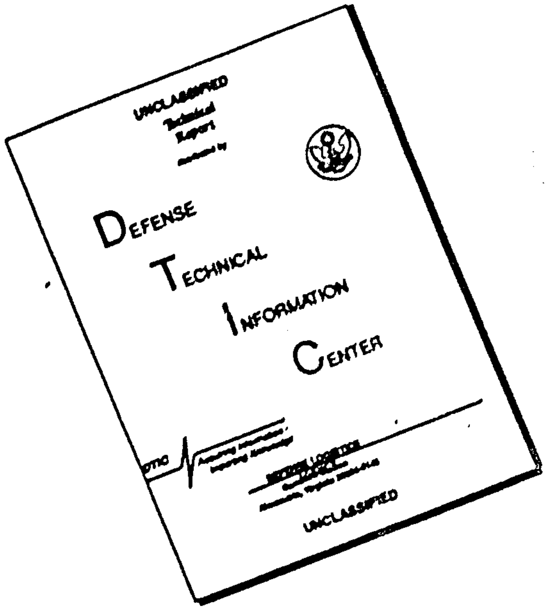

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To: Office of Naval Research
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Attention: Head, Air Branch, Naval Sciences Division

Via: Bureau of Aeronautics Representative
Palo Alto, California

Subject: Propelloplane Transport Aircraft Study, Contract Nonr 1657 (00), Final Summary Report dated 15 May 1956, Transmittal of.

Enclosure: (a) Five (5) Copies of Subject Report.

1. The final summary report of the Propelloplane Transport Aircraft Study, Contract No. Nonr 1657 (00), is submitted herewith. Delivery to other agencies and contractors is being made in accordance with the attached distribution list.

HILLER HELICOPTERS

R A Wagner

R. A. Wagner
Chief Engineer

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FINAL SUMMARY REPORT

Contract No. Nonr 16[illegible] ([illegible])

Report No. Summary Report

Title Propelloplane Transport Study

Date May 15, 1956

By M. Guerrieri

Approved J. N. Stuart III

Approved R. Wagner

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SUMMARY

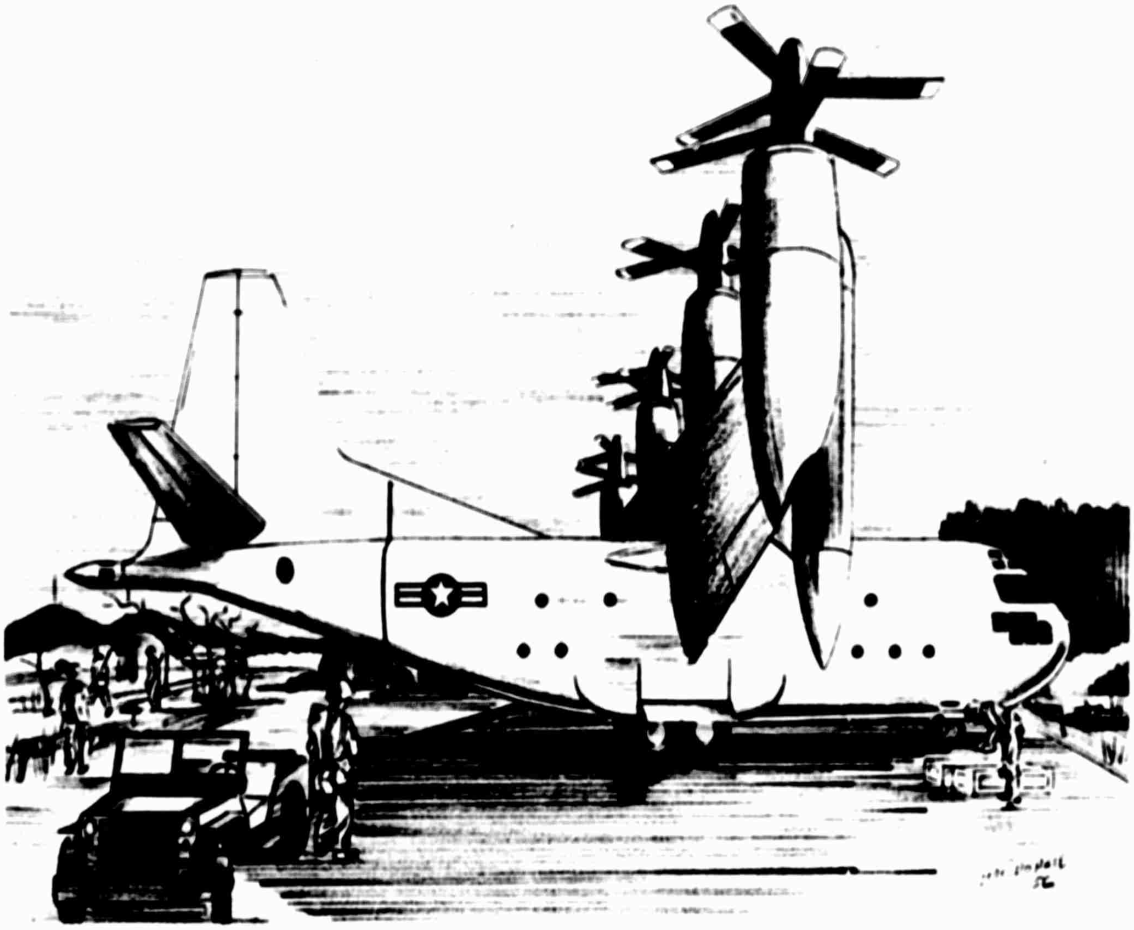
The theoretical and experimental justification for the performance, stability and control of tilting-wing Propelloplanes is contained in earlier NACA wind tunnel and free flight model tests and theoretical investigations conducted by Hiller Helicopters as part of this study. The significant conclusion reached as a result of these researches is that the wing, in transition from hovering to forward flight, contributes immediately to the lift of the aircraft and makes possible equilibrium in flight at very low forward speeds. Of equal importance is the fact that the thrust and power required during transition decreased steadily from the maximum value required in hovering.

The practicability and all-around best possibilities of the propeller-lifted, tilting wing aircraft as a solution to the operational problem of providing air mobility for combat troops and cargo is demonstrated by two preliminary designs of Propelloplane Transports which employ engines scheduled to be available in 1958 and 1960, respectively. A third design, based on the estimated characteristics of engines that will become available in 1965 is developed in considerable detail to show the outstanding performance improvements that may be expected due to improvements in engine performance alone.

Model 1048-A, the 1965 aircraft, performs the specified mission without compromise and at a design gross weight of 71250 pounds.

Model 1048-B, with Allison 550-B1 engines, scheduled to be available in 1960, and using water injection, when necessary, to permit meeting the hover ceiling requirements, also performs the specified mission but at a take-off gross weight of 101,000 pounds.

Model 1048-D is identical to Model 1048-A except for the engines, gear boxes and propellers. Eight Allison 501-D8 gas turbines, scheduled for production in 1958, drive four dual-rotation, eight-blade propellers approximately 19 feet in diameter. These propellers use a currently available Curtiss-Wright blade design. By using water injection and taking off at an overload gross weight of 83,600 pounds, Model 1048-D can carry a payload of three tons, with a radius of action of 310 miles, assuming take-off from 6000 feet altitude and 95°F. With standard temperatures at this altitude, Model 1048-D would be able to carry the full four ton payload the entire radius of 425 miles. This machine, is therefore, recommended for immediate development.



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FIGURES, TABLES AND DRAWINGS

INTRODUCTION

After World War II the first successful VTOL aircraft, the helicopter, was energetically developed. It had received its baptism of fire in small numbers during the last months of the war, but the Korean conflict became the proving ground for large scale testing of the helicopter in combat, and it was there that it earned recognition of its indispensable qualities for military transport missions. By the same token, the inadequacies of reciprocating engine driven, rotor-lifted aircraft, for use in many future combat transport situations was observed by Army and Marine Corps leaders.

Concurrently, post-war development of turbo-jet and turbo-prop power plants opened the way to the possibility of designing vertical rising aircraft not involving the use of large diameter, articulated or semi-articulated rotors, and many schemes were advanced for exploiting this possibility. The most impressive early results were the two Navy VTOL fighters, the XFY-1 and the XFV-1.

In 1954 personnel of the Army Transportation Corps, recognizing that comprehensive engineering studies were required for guidance in future development of combat transport aircraft, initiated a broad cooperative program of study and evaluation of various VTOL and STOL aircraft concepts.

Because of its prior history of interest in propeller-lifted aircraft and as a pioneer exponent of the tilting-wing turbo-propeller lifted concept, Hiller Helicopters was awarded in March, 1955, Contract Nonr-1657 (00) to study and evaluate the development problems involved in this segment of the VTOL aircraft program.

In order to make possible a valid comparative evaluation of the several aircraft designs issuing from the different groups involved in the program, a statement of the operational problem and the uniform design conditions to be used as a basis for study was formulated at a meeting of the Military and contractor's representatives at the Office of Naval Research on April 27, 1955, and amplified by later meetings and directives.

Within the frame work established by specification and agreement, the primary objective of the work to be performed by Hiller Helicopters was to make a preliminary design of the optimum tilting-wing turbo-propeller lifted aircraft capable of accomplishing the specified mission. A summary of the results of that work is presented in this report.

SECTION I - DEFINING THE PROBLEM

A. MISSION REQUIREMENTS:

The operational problem and specified characteristics of the VTOL category of aircraft were stated as follows:

a)	Payload	8000 lbs. out 4000 lbs. return
b)	Take-Off Distance	0' over a 50' obstacle
c)	Cabin Size	9' x 9' x Length Required for 35 Troops
d)	Cargo	35 Combat Troops or Equivalent Weight of Vehicles or Equipment
e)	Hover Ceiling	6000' Altitude and 95°F. Ambient Temperature
f)	Minimum Cruise Speed	300 MPH
g)	Radius of Action	425 Statute Miles
h)	Flight Profile	Cruising Altitude Optional Except for 20% of Radius Adjacent to Destination at Sea Level
i)	Landing Surface	For Rolling Take-Off μ = .2; UCI = 15
j)	One Engine Out Performance	Aircraft to Remain Controllable following failure of One Engine and be able to make a "Controlled Crash" Landing

Several items of considerable importance in their effect on the parameters of the aircraft were necessarily unspecified in order to accommodate a wide range of types. In regard to these optional conditions, assumptions were made which seemed compatible with the mission and type of aircraft being considered by this contractor:

1) <u>Hover Duration:</u>

The time required to takeoff, climb vertically to 50 feet altitude and convert to forward flight was assumed to be one minute. A total time of [illegible] minutes per mission was allowed for take-offs, conversions, and landings. Measurement of the time required for fully loaded Douglas DC-6 and Lockheed Constellation aircraft to accelerate from rest and climb to approximately 50 feet indicates that the assumed time of one minute is excessive. The low power loading of VTOL aircraft compared to fixed wing airliners assures a much higher acceleration and indicates that under normal conditions considerably less time would be required. The wing tilt actuating mechanism was designed to tilt the wing 90° in 20 seconds.

2) <u>Cruising Altitude:</u>

Cruising Altitude has been arbitrarily limited to 25,000 feet to make possible safe operation without pressurizing the cabin. This assumption possibly imposes a penalty upon the design, because in addition to the usual performance gains associated with increased altitude, the increased propulsive efficiency of the propellers, which are necessarily too lightly loaded in forward flight at low altitudes, might more than compensate for the increased structural weight and pressurizing equipment. The effect of altitude was not included in selecting the parameters of the optimum aircraft, because it would increase the work required beyond our capacity in the scheduled period, and because the intended employment of the aircraft accents its low altitude capabilities. The effect of cruise altitude on mission performance for the final optimum design is shown in Figure 10.

3) <u>Provision for Engine-Failure Safety:</u>

The requirement for ability to make a "controlled crash" landing following failure of one engine is the least amenable to proof outside of actual experience. Our designs are based on the premise that if adequate reserve power is available to reduce the the rate of descent to a moderate value following failure of one engine and reduction in power of one other engine as required to obtain trim, plus some small allowance for roll control, then interconnecting shafts may be dispensed with. The optimum aircraft will hover out of ground effect at 5400 feet altitude in the standard atmosphere with the most critical power section inoperative and the remaining power sections delivering normal rated power. The

incidence of "controlled crash" landings should thus be a negligible risk. Under the most adverse conditions of hovering at [illegible] feet above the ground at [illegible] feet altitude and [illegible]°F., abrupt failure of one power section followed by instantaneous application of Military power from six of the remaining seven operative engines would result in a velocity of descent at impact of less than [illegible] feet per second.

4) Cruising Speed:

The specified maximum cruising speed of 3[illegible] miles per hour was assumed to be the actual cruising speed throughout the study. Power plant management during cruising flight was the subject of a separate study aimed at determining the optimum division of (reduced) power among the eight installed power sections.

5) Load Factors:

Specification of limit load factors is necessary for those components of the aircraft whose weights can not be estimated from empirical formulae derived from existing aircraft. For the tilting-wing aircraft these include the wing weight and weight of hinges, actuating mechanism and control devices. Load factors closely approximating those specified by applicable Civil Aeronautics Authority requirements for aircraft of similar size and function were selected.

SECTION II - DESIGN VARIABLES

A. Configurational Variables:

The major alternative configurations considered in this study prior to the selection of the final design are illustrated in Figure 1. The most basic of these is the number and arrangement of power plants, propellers, and nacelles. Preliminary weight estimates indicated that the two nacelle configuration was inferior to the four nacelle configuration in aircraft larger than approximately 60,000 pounds, and more detailed recent studies made in connection with another model indicate that, depending upon the hover ceiling and power plant characteristics assumed, this weight may be as low as 40,000 pounds. Practical considerations, such as maintaining moderate propeller diameters, reducing gear box sizes, and eliminating the interconnecting shafts, also, influenced the decision to use four nacelles.

Of the two alternative four-nacelle configurations illustrated, the four-engine version with interconnecting shafts unquestionably suffers a weight penalty compared to the eight-engine non-interconnected configuration. However, if the interconnecting gear boxes and shafting is designed to have only a short life for full emergency load and in normal operation carries only the unsymmetrical load due to control movements and transient variations in propeller load due to yawing, different rates of pitch change between the separate propellers, and other short term effects, the system is not prohibitively heavy. However, the undesirable cost, complexity, maintenance difficulties, and vibrations associated with long shafts led to the decision to settle on the four-nacelle, eight-engine configuration as the basic design for this study.

Four methods of providing for auxiliary longitudinal and directional control in hovering are illustrated. The method involving the use of bleed air from the main engine compressors was clearly ruled out due to the detrimental effect on engine efficiency of the large quantities of bleed air required. Our estimates indicated that from a weight standpoint tail rotors and tail jets plus the fuel required for their operation were roughly equivalent with some advantage accruing to the more efficient thrust producing rotors. However, in our judgment the advantage was not great enough to warrant the complication, drag in forward flight, vibration, and maintenance difficulty incurred by their use. The high specific thrust, small size turbo-jet engines now being produced are ideally suited to this short life, intermittent operation application.

Three fuel storage locations are illustrated, each having some advantages. For maximum aerodynamic and structural efficiency the wing tip location is favored. In the final optimum design the outboard nacelles were located at the tips so that the underslung tanks were required. This position aids in obtaining proper center-of-gravity movement of the aircraft during transition from vertical to forward flight and is favored from a safety and constructional standpoint over the fuselage hold location.

The selected landing gear arrangement consists of a wheel and skid combination which provides a rolling contact area having a Unit Construction Index of 41 and is adequate for use on flexible pavements and landing mats. With the skids lowered for vertical landing on unprepared surfaces, the contact area is sufficient to give a pressure approximately the same as that of a truck, 3/4 ton, 4 x 4, weapons carrier.

For an all-wheel landing gear, estimates indicate that the multiple, small, high pressure wheels weigh less than the more conventional dual tandem large, low pressure arrangement, for the same U.C.I. The compromise skid and wheel arrangement is appreciably lighter than either of these arrangements.

The selection of an unpressurized cabin has been previously explained.

The selection of dual rotation propellers was arrived at as part of the optimization analysis of the basic parameters.

B. Parametric Variables:

The number of parametric variables subjected to a systematic variation as part of the process of selecting the optimum aircraft included all of the fundamental performance parameters and as many additional variables as permitted by the inevitable necessity of rationing our efforts to accomplish the study objectives within the period available. The following parameters were considered:

a) Gross Weight
b) Wing Loading
c) Aspect Ratio
d) Propeller Disk Loading
e) Propeller Tip Speed
f) Number of Blades
g) Blade Activity Factor

C. Specification of Furnishings and Equipment:

It has been observed that considerable variation exists among the various groups concerned in the present program as to the weight allowance made for the aircraft furnishings and fixed equipment. In this study a conscientious effort was made to make weight provision for all the numerous pieces of operational equipment ultimately demanded in a fully developed military transport aircraft. The list of items considered was adapted from the standard furnishings and equipment groups of currently operational military cargo aircraft; therefore this group weight is subject to review by the procuring agency if it appears that certain items are superfluous in the intended employment of the aircraft.

SECTION III - RESULTS

With the tools and methods developed in the work reported in the preceding section, three preliminary designs of tilting-wing turbo-propeller lifted aircraft have been produced. These are designated Propellcplane Transport Models 1048-A, 1048-B, and 1048-D, and represent aircraft that could be available in 1965, 1960, and 1958, respectively.

The study was principally directed toward the design of Model 1048-A. At the request of the procuring agency, additional studies were made to develop Model 1048-B, designed around the Allison Model 550-B1 gas turbine, scheduled for availability in 1960. Model 1048-D was included to show how minor revisions in the specified mission requirements would permit immediate development of a practical machine.

A General Arrangement Drawing of Model 1048-C, a two-nacelle configuration, is included for information. Work on this design was not carried beyond a preliminary weight estimate when it became obvious that it could not be competitive with the four-nacelle configuration.

General Arrangement Drawing 1048-A-001 and Inboard Profile Drawing 1048-002 apply specifically to Model 1048-A. Similar drawings for Models 1048-B and 1048-D were not prepared because of their nearly identical features. The differences in dimensions of the three models are listed in the table of leading particulars.

A. DESIGN FEATURES:

1. Pilot's Cabin:

Weight and space provisions have been made for a pilot, copilot, and flight engineer. Access to the pilot's cabin is provided through an integral side door and ladder or through the door leading to the cargo compartment. An emergency escape hatch and tube to the bottom of the fuselage is also provided. Weight and space provision for the electronic and communication equipment is made on the flight deck adjacent to the flight engineer's station.

2. Cargo Compartment:

Cargo compartment dimensions are 8' x 9' x 33', and it has a capacity of 35 infantry troops or 18 litters or one truck, 1-1/2 ton, 6 x 6, cargo and personnel carrier, or 3 trucks, 1/4 ton, 4 x 4, utility. The large, unobstructed, rear loading ramp may be lowered for ground loading or raised to truck bed height.

3. Landing Gear:

The fully retractable combination skid and wheel landing gear is proposed as the lightest, simplest arrangement for providing adequate flotation for landing on soft unprepared areas and adequate tire contact area for operation from paved runways. The skids are hydraulically retractable to the forward flight landing position. The landing gear is accessible from within the aircraft.

4. Nacelles:

The eight power sections are geared in pairs to four dual-rotation six-bladed propellers. Firewalls between the power sections and individual oil tanks and coolers are provided for maximum protection against engine failure. Overrunning clutches between the power section output shafts and gear box input shafts provide for disengagement of a failed power section or for voluntary shut down of power sections in cruising.

5. Wing-Tilt Mechanism (Drawing 1048A-003):

Structural efficiency of the wing is not impaired by the hinged connection to the fuselage. The large cross sectional area, two-spar, tapered, cantilever wing beam is continuous from tip to tip. The wing is hinged at the rear spar, located at the 50 percent chord station. Coordinated ball bearing screw jacks, powered by a central 40 horsepower hydraulic motor, tilt the wing through its 90° tilt range in twenty seconds, the approximate time required to accelerate the aircraft from hover to airplane flight speed. An emergency standby electric motor and hand crank are available to actuate the screw jacks in the event of hydraulic system failure.

The critical compression load on the screw jacks was found to occur on the ground when a horizontal decelerating force is applied to the aircraft with the wing in the vertical position. Hydraulically actuated lock-pins secure the wing in the airplane configuration.

6. Control Functions (Drawings 1048A-004 and 1048A-005):

In addition to the usual airplane surface controls, Models 1048A, 1048B, and 1048D are provided with auxiliary means for control in hovering and low speed forward flight. Longitudinal and directional control are provided by directing the exhaust gases of a small turbo-jet engine, mounted in the tail of the aircraft. Lateral control is obtained by varying differentially the power output of the power sections on opposite sides of the aircraft in response to motions of

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Propell [illegible]
Contract [illegible]

[illegible] pilot's [illegible]. [illegible] desirable to render the ailerons [illegible], because if they were to function in their normal manner, [illegible] moments caused by [illegible] of the propeller slipstream [illegible] ailerons [illegible] lateral [illegible]. Conversely, [illegible] associated with lateral control [illegible] must [illegible] eliminated. Drawing [illegible] A-[illegible] mechanical [illegible] of accomplishing [illegible]. [illegible] that the relationship [illegible] ratio of [illegible] altered to [illegible] requirements [illegible] actual [illegible].

Views A-A and B-B of that drawing show how large numbers of control cables may be routed from the fuselage to the wing with negligible change in cable tension occurring due to wing tilting. It was found that if 1/[illegible] inch diameter control cables were assumed, the change in tension due to wing tilt motion is less than [illegible]00 pounds during the cycle. The tensions at the beginning and end of the cycle are equal.

Drawing 10[illegible]A-005 shows how the exhaust gases from three turbo-jet engines converge in a common nozzle and are [illegible] out the tail jet through guillotine-type valves. Before converging the pressure energy of the flow from each engine has been converted to velocity so that back flow cannot occur through a stopped or failed engine. Any two of the three installed units have sufficient capacity for control in the most critical flight conditions. These turbo-jets are operated only during the take-off, conversion, and landing. They may also be used as auxiliary power sources for starting the main engine.

B. <u>LEADING PARTICULARS AND PERFORMANCE CHARACTERISTICS:</u>

Model 1048A and Model 1048D are identical in design except for the installed power plants and propellers. Model 1048A is the optimum, i.e., the minimum gross weight aircraft, capable of accomplishing the mission using engines having the characteristics which are estimated to be attainable by 1965. Model 1048D is based on the guaranteed characteristics of the Allison 501-D8 engines scheduled for production in 1958 and takes advantage of the increased performance obtained by the use of water injection. By making the initial take-off with water injection and with a 20 percent overload, Model 1048D is able to accomplish a reduced mission which is compared graphical with the specified mission

in Figure 2. The propeller blades specified for Model 1048D are components of a Curtiss-Wright propeller currently in production. Model 1048D represents, therefore, an immediately developable, practical Propelloplane transport aircraft.

Model 1048B represents a close approximation to the optimum aircraft based on use of the Allison [illegible]0-B1 gas turbine scheduled for production by 1960, and using propellers which are smaller than designs currently being developed for use by 1960. By using water injection, Model 1048B can perform the complete mission without compromise. The comparative weights of Models 1048A, 1048B, and 1048D are shown in Figure 3. Complete Group Weight Statements for each model are tabulated in Table I. Figure [illegible] shows the percentage weight breakdown of Model 1048A. The weight of the turbo-prop engines, their reduction gearing, the lifting propellers, and the tail turbo-jet engines, grouped together as a power plant weight, becomes almost equal to the airframe and controls weight. 30 percent of the gross weight is still available for useful load at the stringent design vertical take-off condition of 95° at 5000' pressure altitude. This figure compares with perhaps about 45 percent for a normal airplane.

The most forward and most rearward c.g. positions anticipated are shown on Drawing 1048A-001. Payload shifts of 50 inches are included within these maximum c.g. travels of 10 inches and 16 inches for the wing level and wing vertical conditions, respectively.

The leading particulars of each model are shown in Table II.

A comparative performance summary is shown in Table III.

C. CHARACTERISTICS OF MODEL 1048A:

The remainder of this section is devoted to a discussion of the outstanding characteristics of the optimum aircraft, Model 1048A.

1. Basic Operating Characteristics:

Figure 5 shows how the low equilibrium forward speeds of the optimum machine increase approximately 20 miles per hour for each 10 degrees of forward tilt of the wing. This machine would thus be traveling about 60 MPH when the wing was tilted 30 degrees forward of the vertical.

Hiller Helicopters' experience with the ducted fan flying platform has indicated that when a flow is forcibly directed, in that case by the propeller duct, in this case by the wing chord, the correspondence between air speed and angle setting is a most positive and precisely defined function.

Figure 6 shows how both the propeller thrust and required engine power both decrease as the wing angle is decreased from the 90 degree vertical position used in hovering and forward speed is gained. These desirable calculated basic characteristics have been generally confirmed by NACA test results. These curves are based upon an analysis of this particular case and include the effect of mounting the outboard nacelles at the wing tips.

2. <u>Propelloplane Stability and Control Characteristics:</u>

The curved lines on Figure 7 show the fraction of gross weight that must be supplied as tail jet up or down force in hovering and the low forward speed portion of transition flight. No tail up or down force is shown to be required at wing angles-of-attack of 60 degrees or less. At this angle and lower angles and at the corresponding forward speeds of 60 MPH and more, the horizontal tail can generate enough pitching moment to trim the aircraft. The small magnitude of these required tail jet thrusts, based upon the results, and consideration of the favorable shift of the aircraft center-of-gravity as the propeller-engine-wing assembly is tilted forward, is noteworthy. Only 2 percent of gross weight is required in up or down jet thrust to trim the machine. Actually, ± 5 percent is made available even with one of the three tail turbo-jet engines inoperative to provide a substantial margin to handle unusual conditions and provide generous power to insure adequately high pitching angular acceleration and thereby the achievement of prompt control response.

In hovering and low forward speed flight we have provided angular acceleration control powers of at least 12 degrees/second^2 about all three axes. The imposition of a transient power increase of 12 percent on one outboard nacelle and a power reduction of 12 percent on the opposite outboard nacelle will give rolling accelerations of this desired magnitude.

Figure 8 shows how the thrust of a turbo-prop can be made to rise from its idling to its take-off power value within half a second after its power control has been advanced to the "full throttle" position. With propeller pitch change rates of up to 20 degrees per second being made available in propellers designed for turbo-prop engine applications, it is evident that adequately rapid controlled variation of propeller thrust can be provided.

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Propellopla[illegible] Transport St[illegible]dy
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3. Mission Performance:

Standard [illegible] Figure 9. [illegible] less than [illegible] [illegible] of [illegible].

[illegible] defined in Figure 10. [illegible] point, of [illegible] altitude [illegible] percent. [illegible] continues at [illegible] feet and [illegible] the radius of action [illegible].

Figure 11 shows [illegible] the radius of action. [illegible] at a [illegible] standard [illegible] extends to the point where [illegible] radius [illegible] is reduced to [illegible] percent of the [illegible] radius of action.

Figure 12 shows the [illegible] distance as a function of gross weight. Since a [illegible] percent increase in gross weight represents a 67 percent increase in useful load, the [illegible] is comparable to present-day [illegible] in useful load capacity, when operated as a conventional [illegible].

SECTION IV - EVALUATION OF PROPELLOPLANE DEVELOPMENT PROBLEMS

Of the development [illegible] will be encountered during the evolution of the Propellopl[illegible] are common to all forms of airborne vehicles and only two can [illegible] uniquely with the Propellop[illegible]lane type. Furthermore, some [illegible] problems [illegible] technical problems [illegible] because the level of technology is adequate to supply solutions [illegible] and strategic conditions warrant the expenditure of resources [illegible] behalf.

Problems that [illegible] anticipated at present may be listed as follows:

a) Propel[illegible] Development
b) Prope[illegible]-Turbine Controls
c) Turb[illegible] Development
d) Auxi[illegible]ary Control Turbo-Jets and Nozzles
e) Wi[illegible] Circulation Control
f) [illegible] System Design
g) [illegible] Pressurization
h) [illegible] Noise Abatement
i) [illegible] Cargo Handling Methods

[illegible]

[illegible] not seen [illegible] mental results [illegible] British turbine [illegible] propellers, but in [illegible] dual rotation [illegible] favor of the slight- [illegible] propellers.

[illegible] the gross weight [illegible] mostly in terms of [illegible] conventional [illegible] the category of aircraft [illegible] is obtained [illegible] dual rotation propellers. However, [illegible] authoritative [illegible] as to the advisability of [illegible] development of dual rotation propellers in this country, expressly for Propelloplanes, for it may well be that in practice, as in the past, single rotation propellers are more feasible. The existence of successful dual-rotation propellers in Great Britain indicates [illegible] they can be developed.

Our study of the first-order propeller blade [illegible] bending stresses during transition from hovering to forward flight indicates that for a Propelloplane having the transition flight characteristics of Model 1[illegible], these stresses are not critical. Again, only actual flight [illegible] give positive assurance that this is the case, but for the present it appears [illegible] development [illegible] critical problems from a [illegible] standpoint.

[illegible]) Propeller-Turbine Controls:

In addition to the usual devices for controlling turbo-propeller power plants, the Propelloplane requires means for varying the propeller blade pitch setting differentially in the nacelles on opposite sides of the aircraft to produce rolling control in response to motions of the pilot's control wheel during hovering and slow speed flight with the wing vertical. This would be accomplished by varying the power settings of the engines. The propeller's constant speed pitch control governing system would correspondingly alter the blade pitch, affecting a change in thrust. Changes in power of about ± 12 percent of normal rated power appear adequate to produce satisfactory rolling moment.

[illegible]ure [illegible] has already been cited as [illegible] and the propeller pitch change mechanism of current designs are insufficiently responsive to power settings to provide satisfactory rates of control response. Development of suitable mechanisms to perform this function is required but offers no extreme difficulties.

A somewhat knottier problem is foreseen in the development of automatic devices for maintaining safe control following failure of a power section under the most critical hovering conditions. If, for example, one outboard engine section failed while the aircraft is hovering at 6000 feet altitude and [illegible]° F., power should be reduced in the opposite outboard nacelle and the remaining operative engines immediately advanced to military power. Normal pilot reaction, assuming that he is initially unaware of the emergency, would be to apply roll control to maintain level attitude and increase the power lever settings to maintain altitude. However, the normal range of roll control travel will normally provide about ± 1[illegible] percent change in power settings, which corresponds roughly to the percentage by which military power exceeds normal rated power. Thus, application of full roll control will not be sufficient to trim the aircraft and automatic means of compensating for this situation and simultaneously signaling the pilot that an emergency exists should be developed. The feasibility of dispensing with inter-connecting shafts may be contingent upon successful development of such a device. Effort in this direction is strongly recommended.

c) Turbine Development:

In propeller-lifted VTOL aircraft propeller efficiency in forward flight is compromised by the essentially constant speed operation of the turbines, in order to maintain reasonable thermal efficiency. The optimum propeller for the cruising condition of a Propelloplane Transport would be about 15 feet in diameter. The larger diameter required for satisfactory static thrust in hovering results in reduced propulsive efficiency in cruising, if the same tip speed is maintained. If the tip speed is reduced 25 percent, the propulsive efficiency can be increased to about 90 percent. In this study propeller tip speed was considered a constant 900 feet per second, which was found to be the optimum compromise value for this mission. The development of twin-spool turbines which permit a wider variation in propeller operating speed without penalizing the turbine efficiency, would improve Propelloplane performance appreciably. This improvement must be weighed against the increased weight, cost, and maintenance associated with the more complicated free turbine engine.

d) Auxiliary Control Air-Jets and Nozzles:

A [illegible] specific [illegible] small size [illegible] are [illegible] [illegible], [illegible] for use [illegible] power, [illegible] improved designs [illegible]. [illegible] special [illegible] cases and [illegible] control [illegible] developmental [illegible] engine thrust [illegible] of the small [illegible] for [illegible] the deflectors are not [illegible]. [illegible] difficulties will be found [illegible].

e) Wing Circulation Control:

The demands made upon the wing of a Propelloplane [illegible] of modern airfoil design. [illegible] pass [illegible] occurs [illegible] transition from hovering to forward flight. [illegible] flected slipstream [illegible] for achieving [illegible] turn the slipstream [illegible] more than twice this [illegible] the airfoil or the airfoil with slots and flaps, [illegible] bination, [illegible] the best characteristics for Propelloplane [illegible] require detailed wind tunnel investigation, [illegible] no extension [illegible] aerodynamic technology is contemplated.

Some wind tunnel study will [illegible] be required of the [illegible] and location of the ailerons or equivalent lateral control devices [illegible] must take over the lateral control function at some point in the transition from hovering to forward flight.

f) Fuel System Design:

Two detail design problems exist in the fuel system of a Propelloplane Transport that are not found in conventional cargo aircraft. The first is providing for uninterrupted flow of fuel from the wing tanks to the engines throughout the [illegible] range of tilting. (If the tanks are located in the fuselage, [illegible] couplings between the fuselage and wing would be needed.) The second problem may exist due to the extremely high rate of climb of the Propelloplane and resultant possibility of fuel boiling, unless a pressurized or refrigerated fuel system is specified.

g) Cabin Pressurization:

The decision whether to pressurize the cabin of a Propelloplane Transport is a problem in operational analysis rather than a development problem. As stated earlier, our study was limited by lack of information and time to make a thorough research into the effects of altitude and cruise speed on the optimum design, but it was clearly indicated that operation

at higher altitudes would improve performance. If tactical considerations make it imperative to operate at low altitudes, then more emphasis should be given to the consideration of free turbine engines or other means (including two-speed transmissions) of lowering the propeller speed in cruising. On the other hand, if altitude is unrestricted, pressurizing the cabin and operating at altitudes where propeller performance at constant speed improves, may be the simplest way of compromising the divergent requirements of high static thrust in hovering and good higher speed performance.

h) Dust and Noise Abatement:

This problem must be acknowledged in all high disk loading, vertical rising aircraft, and no practical solution, in most instances, can be given at this time. It is incumbent upon the commanders and strategists which understand the military advantages to be gained from the use of vehicles conferring true air mobility to combat elements to devise plans and tactics suited to the shortcomings as well as the outstanding qualities of their weapons. For example, single operations or infrequent operations from grass-covered sites would probably be entirely satisfactory with Propelloplanes because of the low residual heat from the gas turbine exhausts and their relatively high location, while surfaces of loose sand or dry bare soil might be less suitable, principally due to piloting rather than mechanical difficulties. It is conceivable that light weight, air transportable fabric, plywood or metal landing mats, similar to the steel pierced plank of World War II air strips, would be adequate to prevent dust storms. Only small areas would be needed, which could be rapidly staked in place.

Of the several VTOL concepts only the helicopter or tilt-rotor convertiplane have lower disk loadings than the Propelloplane so that it appears that the problem of dust and noise control will be further aggravated by other types capable of this mission.

i) Modern Cargo Handling Methods:

Military sponsored studies of methods of handling air cargo currently in progress show that remarkable gains in transport capacity are attainable by using engineered, integrated cargo handling systems. The spectacular performance of the Propelloplane Transport would be improved more by modern method of loading and unloading cargo because of the lower block-to-block time. This item is cited merely to call attention to the work that is being done in this field and to suggest that is is appropriate to consider its implications at the earliest stages of planning for future cargo aircraft.

CONCLUSION

The results of the study conducted by Hiller Helicopters for the Army Transportation Corps under Contract Nonr 165[illegible] ([illegible]) with the Office of Naval Research substantiate these conclusions:

1. The Concept of tilting-wing turbo-propeller lifted transport aircraft is intrinsically sound and technically feasible.

2. The design and construction of a Propelloplane capable of performing the specified mission is possible, using engines that are scheduled for production in 1960.

3. Design and construction of a Propelloplane capable of performing a slightly reduced mission, using engines available for production in 195[illegible], is possible, [illegible] in the gross weight of the machine below that of the machine capable of the specified mission.

4. The development problems involved in the design and construction of a Propelloplane are numerous but within the range of our present technology.

APPENDIX - BIBLIOGRAPHY AND REFERENCES

Literature surveys, collecting data, and developing analytical methods for handling the problems unique to multiple-engine propeller lift aircraft constituted the greater part of the work of this study. Correspondence and conferences with the major engine and propeller manufacturers and with personnel of the National Advisory Committee for Aeronautics, Ames, and Langley Laboratories were held frequently throughout the course of the study. Specific mention must be made of the assistance rendered by the Propeller Division, Curtiss-Wright Corporation, in developing an empirical method of estimating the weights of propellers. The information received from Mr. Charles Zimmerman of the Langley Aeronautical Laboratory in regard to the use of articulated propellers was also helpful.

The details of the sources of information and analytical methods used in this study are contained in Hiller Helicopters Engineering Reports submitted with the Progress Reports and with this report.

The following bibliography lists the Hiller Engineering Reports that form a part of the work submitted under Contract Nonr 1657 (00) and other references consulted in the course of this study.

A. Hiller Helicopters Engineering Reports Submitted as Part of Contract Nonr 1657 (00):

	Title	Submitted
1.	Report No. 461.1, "Variation of Propelloplane Wing Weight with Gross Weight, Aspect Ratio and Wing Loading".	August 15, 1955 as part of Progress Report No. 2.
2.	Report No. 123.4, "Application of Model Propeller Test Moment Data to Full Scale Propellers".	October 15, 1955 as part of Progress Report No. 3.
3.	Report No. 461.3, "A Simplified Theoretical Investigation of a Wing-Propeller Combination Through a Range of Angles-of-Attack from 0° to 90° and a Comparison with Experimental Results."	October 15, 1955 as part of Progress Report No. 3.
4.	Report No. 630.5, "Generalized Shaft Turbine Characteristics".	December 15, 1955 as part of Progress Report No. 4.

[illegible]

5. [illegible] - P[illegible]".

6. [illegible] for Transport Propelloplane [illegible] - [illegible] as [illegible] [illegible] Summary [illegible].

7. Report No. [illegible], "[illegible] in Terms of Parametric Design Analysis for Propelloplane Transport Study - Contract Nonr 1657 (00)". May 1[illegible] as part of Summary Report.

8. Report No. [illegible], "Propelloplane Sta[illegible] and Control Report". May 1[illegible], 1956 as part of Summary Report.

9. Report No. A.D-1[illegible], "Transport Propelloplane Operational Analysis". May 1[illegible], 19[illegible] as part of Summary Report.

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2. McLemore, H.C., and Cannon, M.D., "Aerodynamic Investigation of a Four-Blade Propeller Operating Through an Angle-of-Attack Range from 0° to 180°". NACA Technical Note 3[illegible]. June, 195[illegible].

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5. "Wind Tunnel Test of a Non-Rotating Propeller", Curtiss-Wright Corporation, Propeller Division, Report No. C-25[illegible].

6. "The 1xP Propeller Vibration Problem and Related Effects", Curtiss-Wright Corporation, Propeller Division, Report No. C-[illegible]131.

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Model CT(6LP) 655-A Propeller
Design 1060/1061-1005-36 Blades (16'0")
Allison XT40-A-613 Engine (.0639) and
Allison XT40-A-14 Engine (.0706)
Lockheed XFV-1 Airplane (Model 081)
Contract NOa(s) 53-645-c Lot 2, Item 7"
Curtiss-Wright Corporation, Propeller Division, Report No. C-[illegible].

9. Curtiss-Wright Corporation, Propeller Division, Unpublished Memos:
(a) "Estimating Formula for Basic Propeller Weight", January 1[illegible], 19[illegible].
(b) "An Approximate Propeller Weight-Strength Formula", October 27, 1955.
(c) "An Approximate Propeller Weight-Aq Relationship", November 11, 1955.
(d) "A More Accurate Propeller Weight Formula Based on the Aq Factor", December 1, 1955.

10. "Procedure and Data for Propeller Performance Analysis", Aeroproducts Division, General Motors Corporation, Report No. 190.

11. Garbell, Maurice A., "The Ground Run of Aircraft in Landing and Take-off in ICAO Units", Garbell Research Foundation, Garbell Aeronautical Series No. 3.

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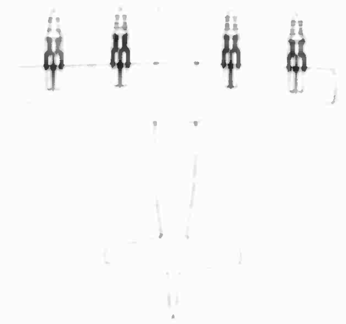
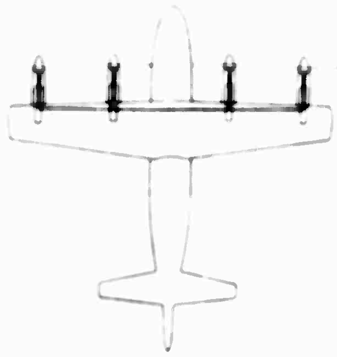
Catalog: "Electric - Mechanical - Turboelectric"
Curtiss Propellers - Current Models for Reciprocating and Turbine Aircraft Engines, September, 1954.

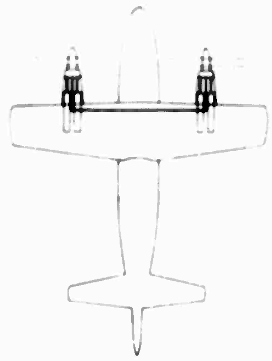
ENGINE AND NACELLES



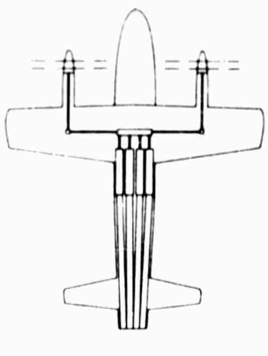
EIGHT ENGINES - FOUR NACELLES
NO INTERCONNECTING SHAFTS



FOUR ENGINES - FOUR NACELLES
INTERCONNECTING SHAFTS

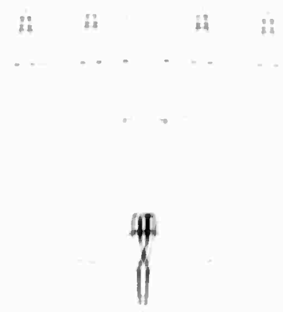


FOUR ENGINES - TWO NACELLES
INTERCONNECTING SHAFTS



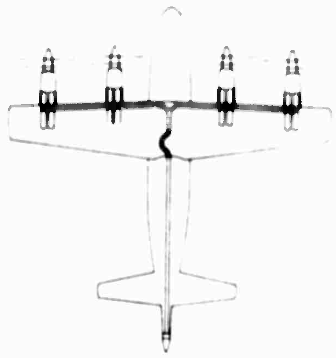
FOUR ENGINES - TWO NACELLES
ENGINES GROUPED IN FUSELAGE

AUXILIARY CONTROL

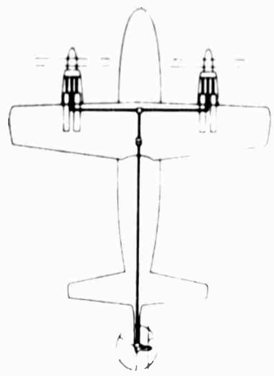


TAIL JET
AUXILLIARY TURBOJET ENGINES

TAIL ROTOR
AUXILLIARY TURBOPROP ENGINE



TAIL JET
MAIN ENGINE AIR BLEED



TAIL ROTOR
MAIN ENGINE DRIVEN

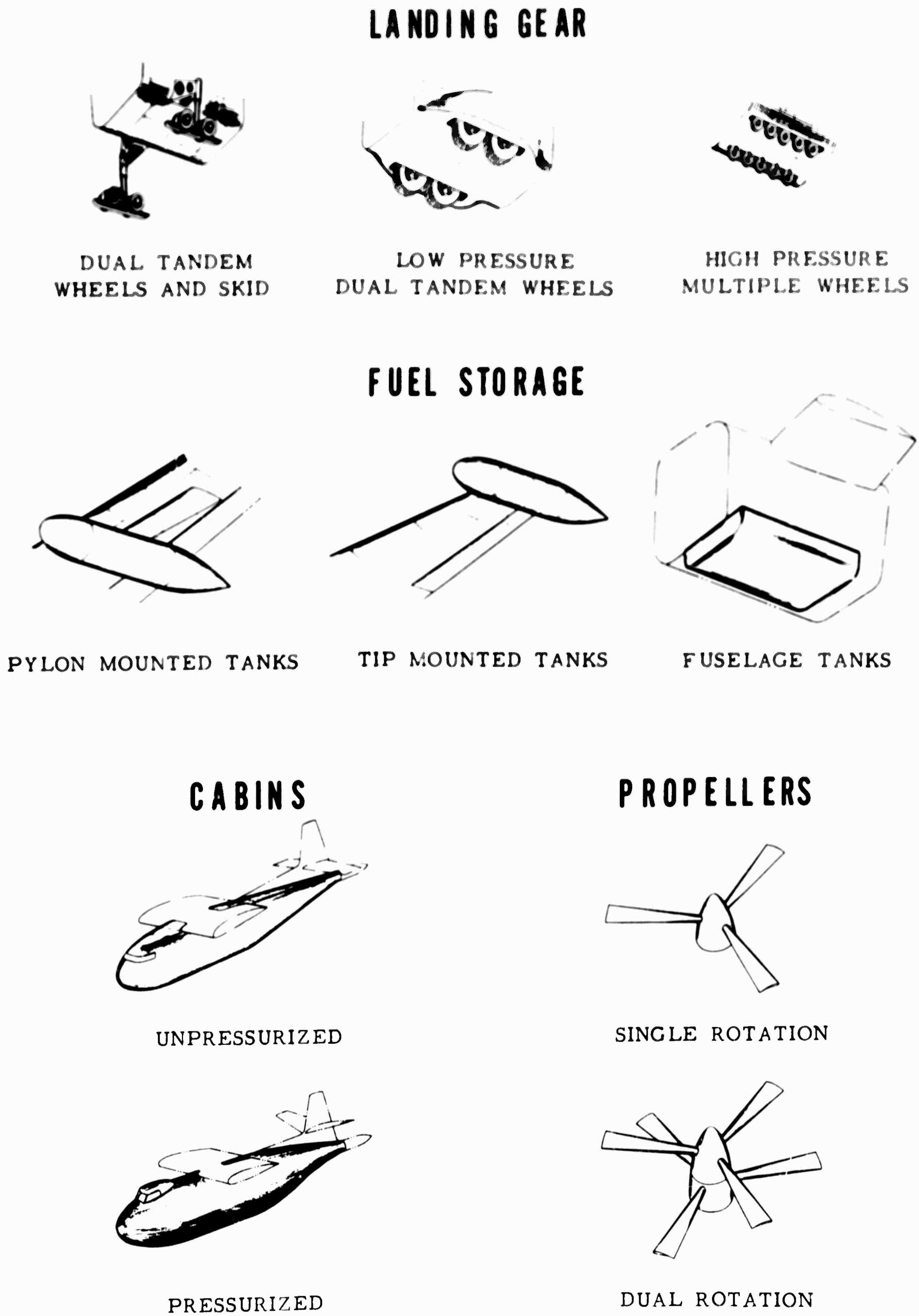

LANDING GEAR
DUAL TANDEM WHEELS AND SKID
LOW PRESSURE DUAL TANDEM WHEELS
HIGH PRESSURE MULTIPLE WHEELS
FUEL STORAGE
PYLON MOUNTED TANKS
TIP MOUNTED TANKS
FUSELAGE TANKS
CABINS
UNPRESSURIZED
PRESSURIZED
PROPELLERS
SINGLE ROTATION
DUAL ROTATION

FIG. 1

MODEL 1048D
PERFORMANCE

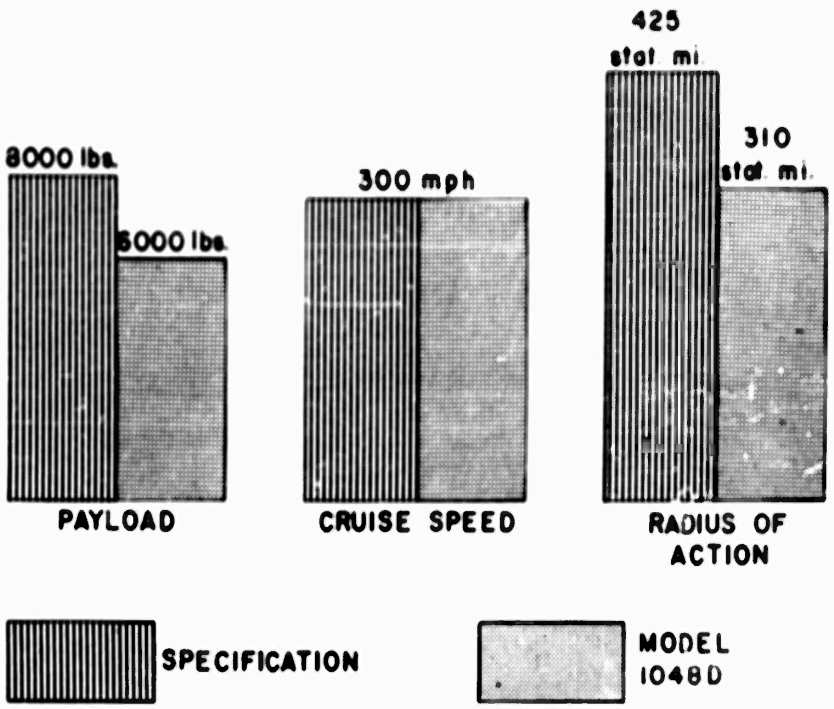
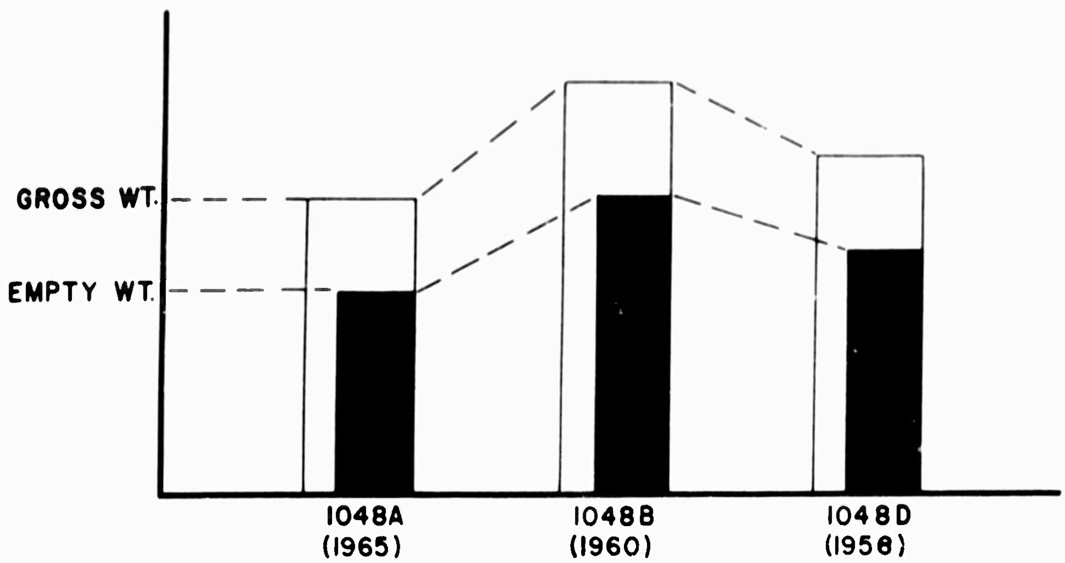


FIG. 2

COMPARATIVE WEIGHTS



GROSS WT.	71250	101000	83600
EMPTY WT.	50200	70935	59820
FIRST LANDING	65650	91050	76000
2nd TAKE OFF	61650	85600	71000

FIG. 3

MODEL 1048A
PERCENTAGE WEIGHTS

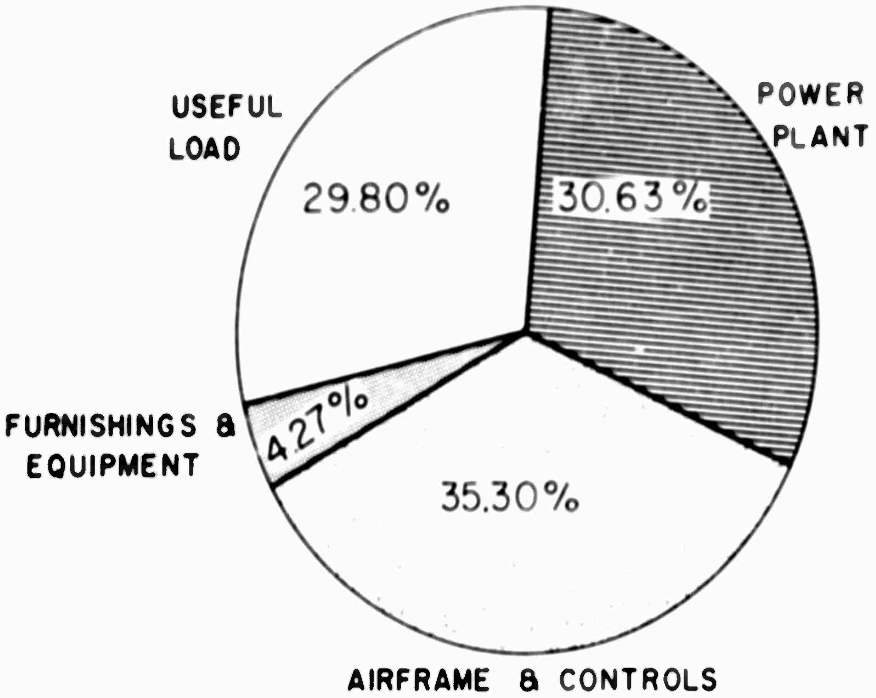


FIG. 4

MODEL 1048A
FORWARD SPEED VERSUS
WING TILT ANGLE

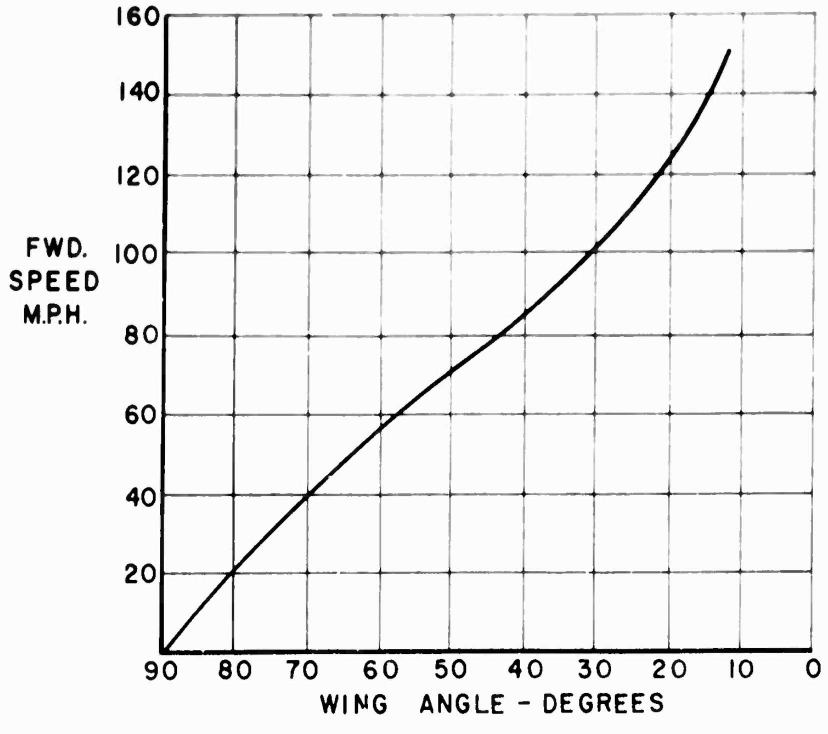


FIG. 5

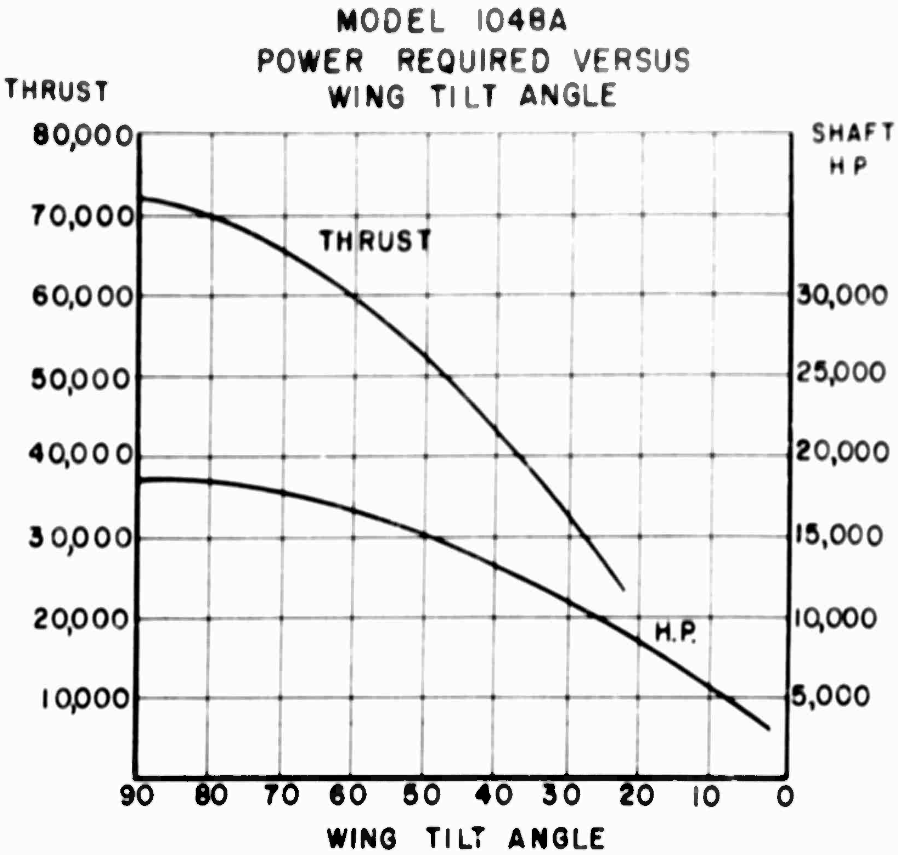

MODEL 1048A
POWER REQUIRED VERSUS
WING TILT ANGLE
THRUST
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
SHAFT
H P
30,000
25,000
20,000
15,000
10,000
5,000
THRUST
H.P.
90
80
70
60
50
40
30
20
10
0
WING TILT ANGLE

FIG. 6

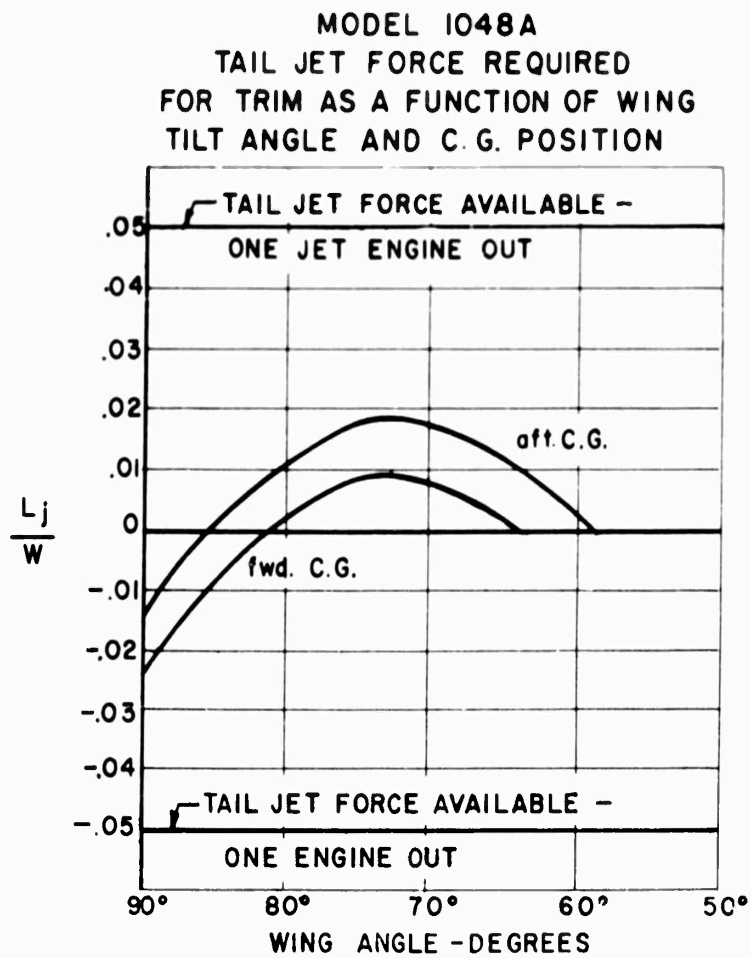

MODEL 1048A
TAIL JET FORCE REQUIRED
FOR TRIM AS A FUNCTION OF WING
TILT ANGLE AND C.G. POSITION
TAIL JET FORCE AVAILABLE -
ONE JET ENGINE OUT
.05
.04
.03
.02
.01
0
-.01
-.02
-.03
-.04
-.05
Lj
W
aft. C.G.
fwd. C.G.
TAIL JET FORCE AVAILABLE -
ONE ENGINE OUT
90°
80°
70°
60°
50°
WING ANGLE - DEGREES

FIG. 7

TYPICAL TURBINE TRANSIENTS FROM TEST RECORDS

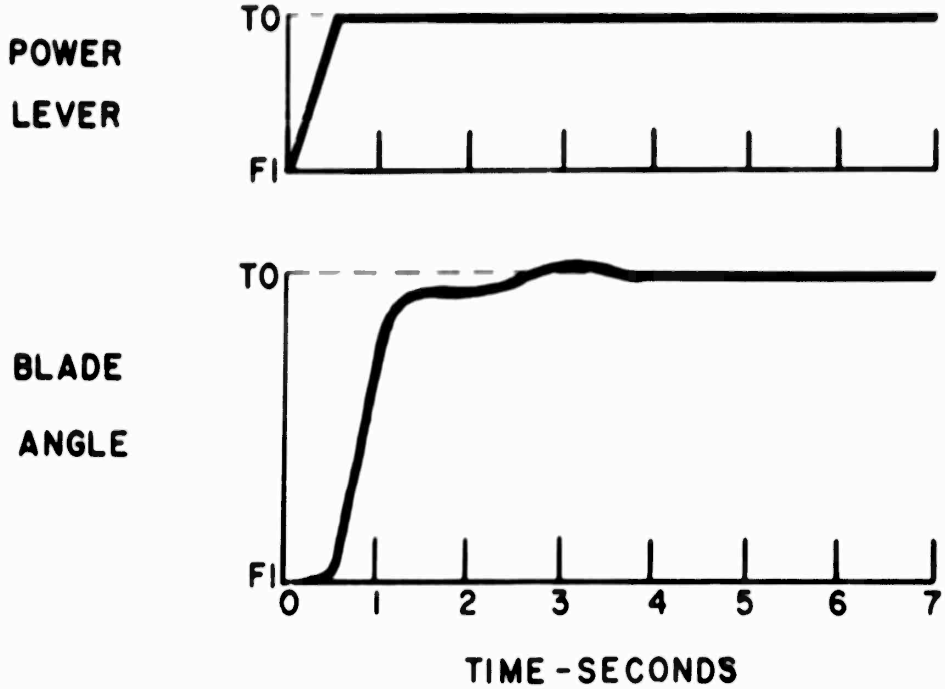


FIG. 8

MODEL 1048 A
MISSION PROFILE

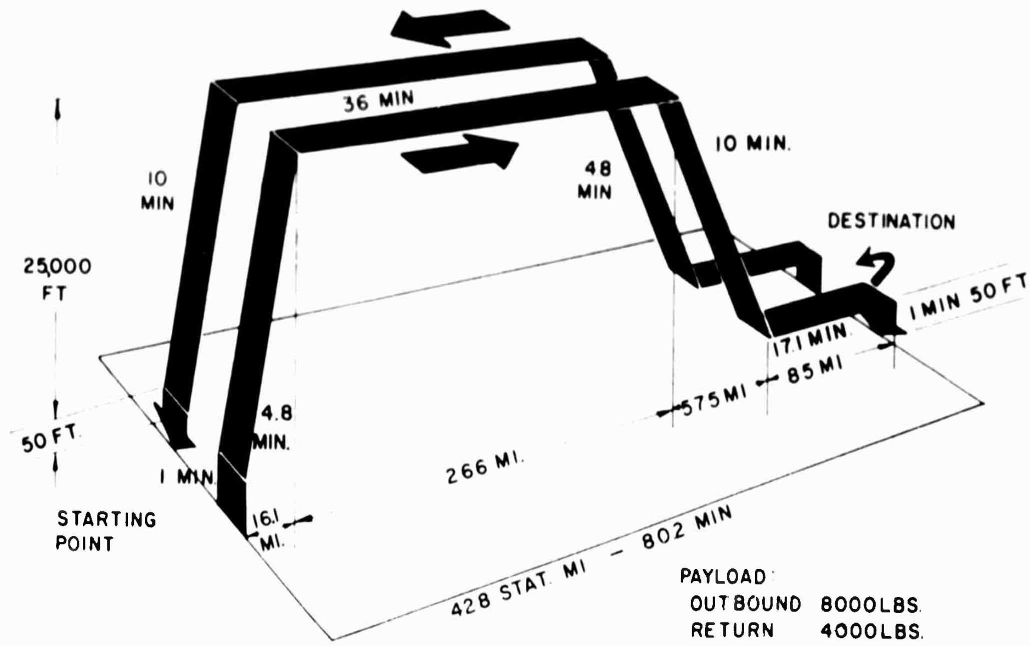


FIG. 9

MODEL 1048 A

PAYLOAD-RANGE PERFORMANCE

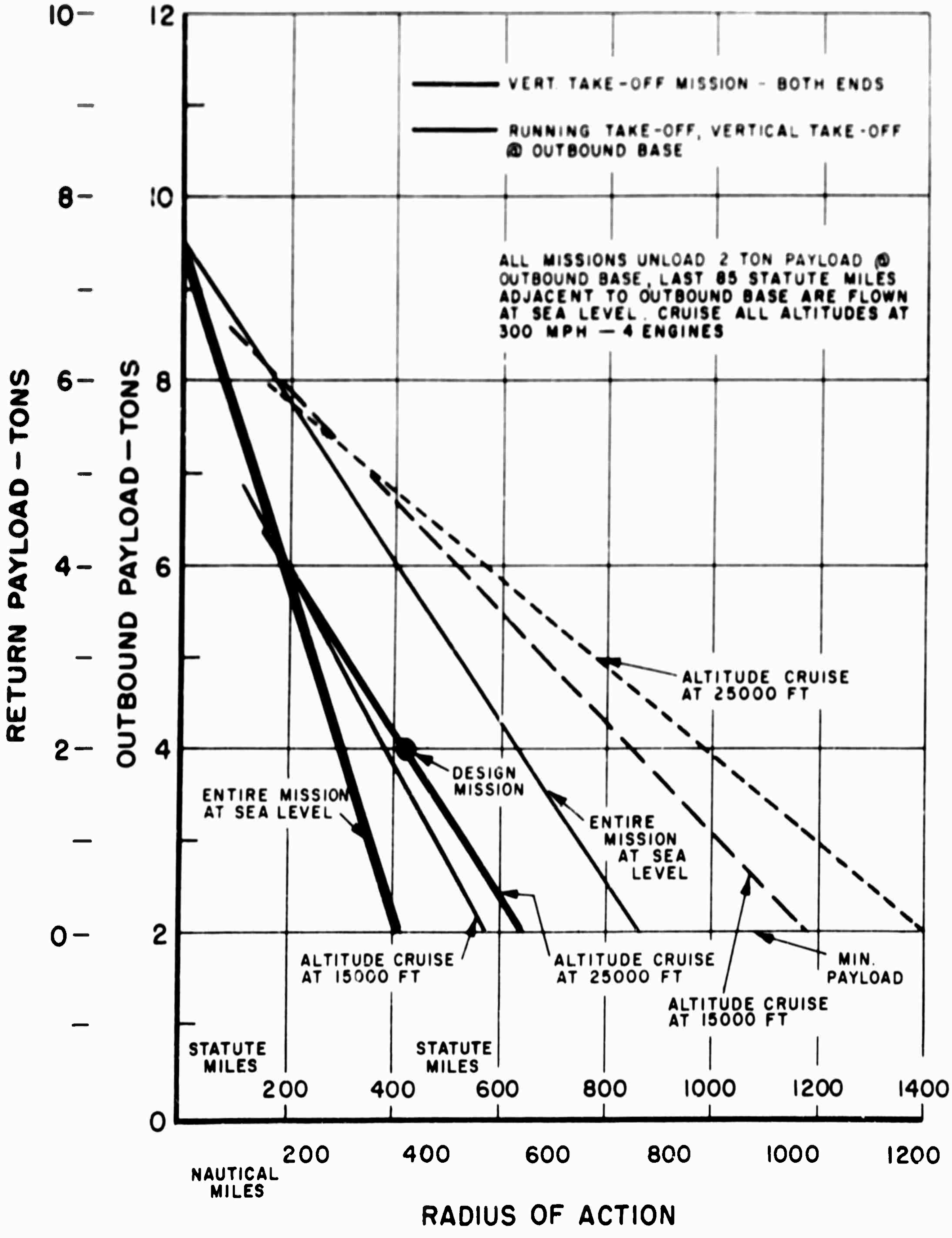


FIG. 10

MODEL 1048 A

HOVER TIME VS RADIUS — SEA LEVEL, STD.

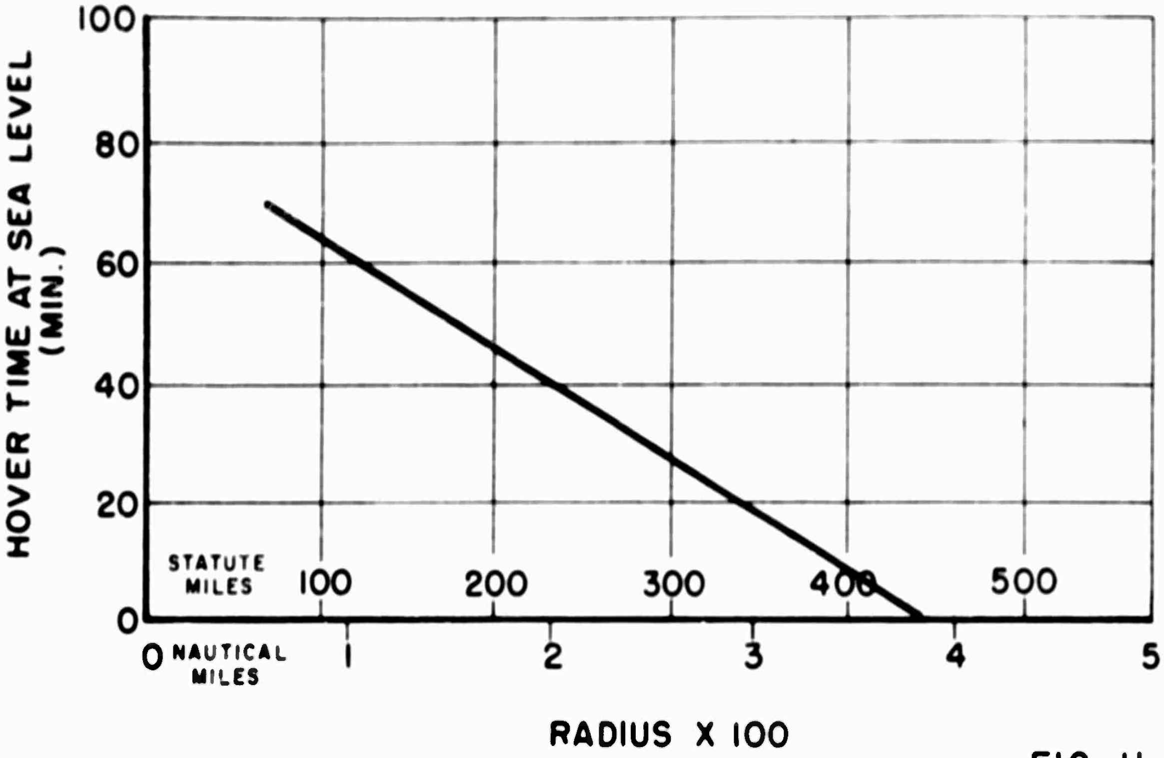


FIG. 11

MODEL 1048 A

TAKE-OFF DISTANCE VS GROSS WEIGHT

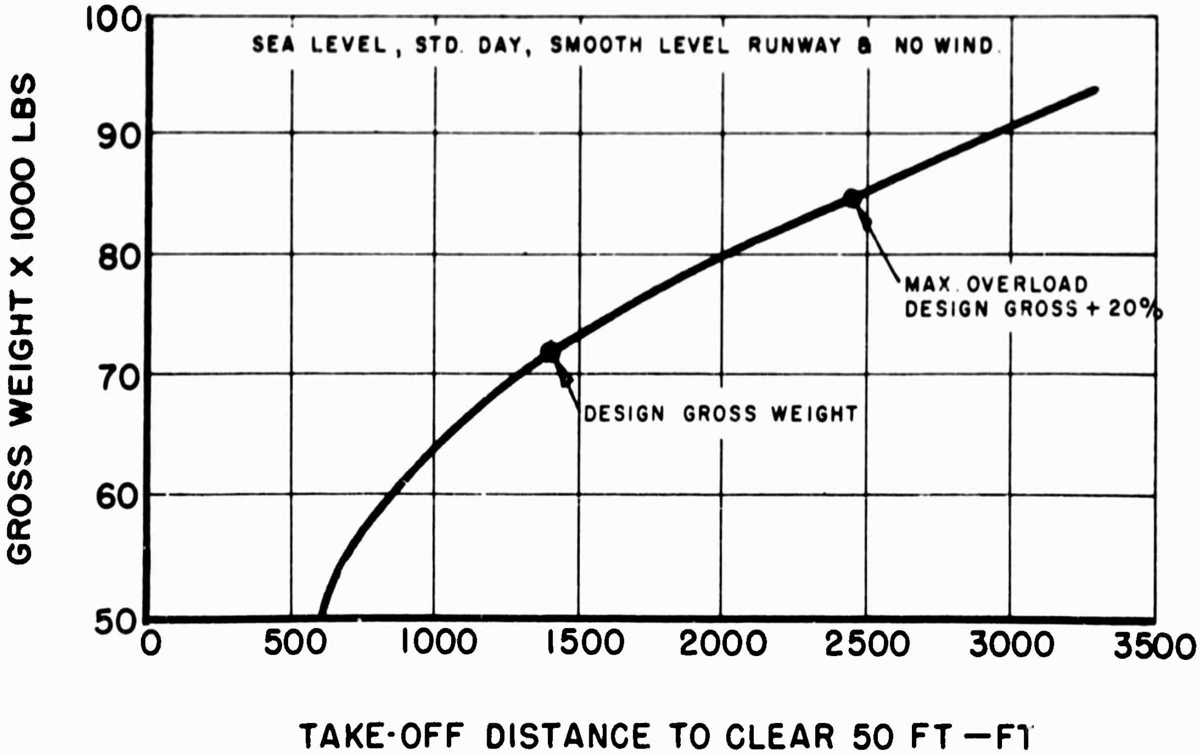


FIG. 12

TABLE I

[illegible]

	[illegible]			[illegible]
1.	Wing Group			[illegible]
2.	Tail Group			[illegible]
3.	Body Group			[illegible]
4.	Alighting Gear Group			[illegible]
5.	Surface Controls Group			[illegible]
6.	Cockpit Controls		[illegible]	
7.	Automatic Pilot		[illegible]	
8.	System Controls		[illegible]	
9.	Wing Tilt Mechanism		[illegible]	
10.	Engine Section or Nacelle Group (4)			[illegible]
11.	Propulsion Group			[illegible]
12.	* Engine Installation - Main (4)		[illegible]	
13.	Transmission and Drives (4)		[illegible]	
14.	Fuel System		[illegible]	
15.	Water Injection System		0	
16.	Propeller Installation		[illegible]	
17.	Propellers (4)	[illegible]		
18.	Spinners (4)	[illegible]		
19.	Propeller Control	[illegible]		
20.	* Supplemental Control Engine Installation (3)		[illegible]	
21.	Supplemental System Control		400	
22.	Instruments and Navigation Equipment Group			[illegible]
23.	Hydraulic and Pneumatic Group			[illegible]
24.	Electrical Group			[illegible]
25.	Electronics Group			[illegible]
26.	Furnishings & Equipment Group			[illegible]
27.	**Accommodations for Personnel		1185	
28.	Miscellaneous Equipment		130	
29.	Furnishings		45	
30.	Emergency Equipment		440	
31.	Air Conditioning and Anti-Icing Equipment Group			[illegible]
32.	Air Conditioning		200	
33.	Anti-Icing		600	
34.	Anti-Icing - Propeller (4)	300		
35.	Anti-Icing - Other	300		
36.	Weight Empty			[illegible]
37.	Useful Load			21070
38.	Crew (3)		600	
39.	Fuel - Mission		11220	
40.	Fuel - Control		930	
41.	Oil		300	
42.	Troops and/or Cargo		8000	
43.	Design Gross Weight			71250
44.	Fuel - Overload			0
45.	Water - Water Injection			0
46.	Take-Off Gross Weight			71250

* Engine installations include air induction systems, exhaust systems, cooling systems, lubricating systems, engine controls, and starting systems.

**Accommodations for personnel includes: 3 crew seats & safety harnesses = 150 lbs.; 35 infantry men seats = 350 lbs.; toilet & washing facilities = 200 lbs.; and oxygen installation (including charge) for 38 men for 3 hours duration = 485 lbs.

TABLE I

GROUP WEIGHT STATEMENT

	MODEL [illegible]			[illegible]		
1.			[illegible]			
2.			[illegible]			
3.			[illegible]			
4.			5250			[illegible]
5.			23[illegible]			[illegible]
6.		[illegible]			[illegible]	
7.		[illegible]				
8.		[illegible]				
9.		[illegible]				
10.			[illegible]			
11.			[illegible]			
12.		[illegible]				
13.		[illegible]			[illegible]	
14.		[illegible]			[illegible]	
15.		[illegible]			[illegible]	
16.		131[illegible]				
17.	[illegible]			[illegible]		
18.	240			[illegible]		
19.	150			150		
20.		[illegible]			[illegible]	
21.		[illegible]			[illegible]	
22.			500			[illegible]
23.			615			[illegible]
24.			1125			[illegible]
25.			500			500
26.			1800			1800
27.		1185			1185	
28.		130			130	
29.		45			45	
30.		440			440	
31.			800			[illegible]
32.		200			200	
33.		600			[illegible]	
34.	300			[illegible]		
35.	300			300		
36.			71435			[illegible]
37.			21565			[illegible]
38.		600			600	
39.		11450			3600	
40.		1215			930	
41.		300			300	
42.		8000			6000	
43.			93000			71250
44.			6550			[illegible]
45.			1450			2900
46.			101000			[illegible]

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[illegible]

LEADING PARTICULARS

Model	[illegible]	[illegible]	[illegible]
Dimensions			
Length (Overall)	[illegible] - 0"	[illegible]	[illegible] - 0"
Width (Outside of Propellers)	[illegible]	[illegible] - 5"	[illegible]
Height (To Top of Vertical Fin)	[illegible]	[illegible]	[illegible]
Weights and Loadings			
Empty Weight, Lbs.	[illegible]	[illegible]	[illegible]
Payload, Lbs.	[illegible]	[illegible]	[illegible]
Main Fuel, Lbs.	[illegible]	[illegible]	[illegible]
Auxiliary Control Fuel, Lbs.	[illegible]	[illegible]	[illegible]
Oil, Lbs.	[illegible]	[illegible]	[illegible]
Water-Alcohol, Lbs.	0	[illegible]	[illegible]
Design Gross Weight, Lbs.	71250	[illegible]	[illegible]
Overload Fuel, Lbs.	0	[illegible]	[illegible]
Take-Off Gross Weight, Lbs.	[illegible]	[illegible]	[illegible]
Wing			
Span (Between Centerlines of Outboard Nacelles)	71' - 10"	[illegible]	[illegible]
Area, Square Feet	792	[illegible]	[illegible]
Aspect Ratio	[illegible]	[illegible]	[illegible]
Taper Ratio	2:1	[illegible]:1	[illegible]:1
Airfoil			
M.A.C.	10' -10"	11' - 5"	[illegible] - 10"
Tail			
Vertical Tail Area, Square Feet	211	251	211
Horizontal Tail Area, Square Feet	232	277	232
Propellers			
Diameter	[illegible] - 7"	21' - 6"	19' - 1"
Number of Blades	6	6	8
Activity Factor	135	[illegible]	[illegible]
Tip Speed	900	900	900
Disk Loading	65.4	64.0	72.5
RPM	926	[illegible]	903
Landing Gear			
Wheel Base	24' - 3"	24' - 3"	24' - 3"
Tread	14' - 7"	14' - 7"	14' - 7"
Tires, Main, 8, Type VII	32 x 6.6	30 x [illegible].8	32 x [illegible].6
Nose 2, Type VII	29 x 7.7	30 x 7.7	29 x 7.7
Contact Area, Square Inches			
Skids Lowered	2546	3630	[illegible]
Skids Raised	971	1380	971
Auxiliary Control Turbo-Jets			
Model	"1965"	MX2273	MX2273
Normal Rated Thrust, Lbs.	2200	2450	2450

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TABLE III

PERFORMANCE SUMMARY

Model	[illegible]	[illegible]	[illegible]
Engines - 2 Each	"[illegible]"	[illegible]	[illegible]
Normal Rated Power @ Sea Level	[illegible]	[illegible]	[illegible]
Military Power @ Sea Level	[illegible]	[illegible]	[illegible]
Speed, Miles Per Hour			
Stall, Sea Level, Std., Power [illegible]	[illegible]	[illegible]	
Cruise, Sea Level	[illegible]	[illegible]	[illegible]
Cruise, 25000 Feet	[illegible]	[illegible]	[illegible]
Maximum, Sea Level (75% NRP)	[illegible]	[illegible]	
Maximum, 25000 Feet (100% NRP)	[illegible]	[illegible]	
Rate of Climb, Feet Per Minute			
[illegible], Sea Level (75% NRP)	[illegible]	[illegible]	
Maximum, 25000 Feet (100% NRP)	[illegible]	[illegible]	
Vertical, Sea Level (75% NRP)	[illegible]	[illegible]	
Vertical, 6000 Feet, 95°F., Maximum Power	[illegible]	[illegible]	
Ceiling, Feet			
Hover, Std. Atmosphere, Maximum Power	[illegible]	[illegible] *	[illegible] *
Service, NRP	[illegible]	[illegible] *	
Hover			
% Maximum Power Required to Hover @ 6000 Feet, 95°F.		[illegible] ●	[illegible] ●
Range, Miles			
Ferry @ 25000 Feet, Cruise Altitude, [illegible] Overload & 10% Reserve	3025	[illegible]	[illegible]
Radius of Action for Specified Mission	[illegible]25	[illegible]	[illegible]

* Calculated at Design Gross Weight of [illegible],000 Lbs.

** Calculated at Take-Off Gross Weight.

● Water-Alcohol Injection Used.

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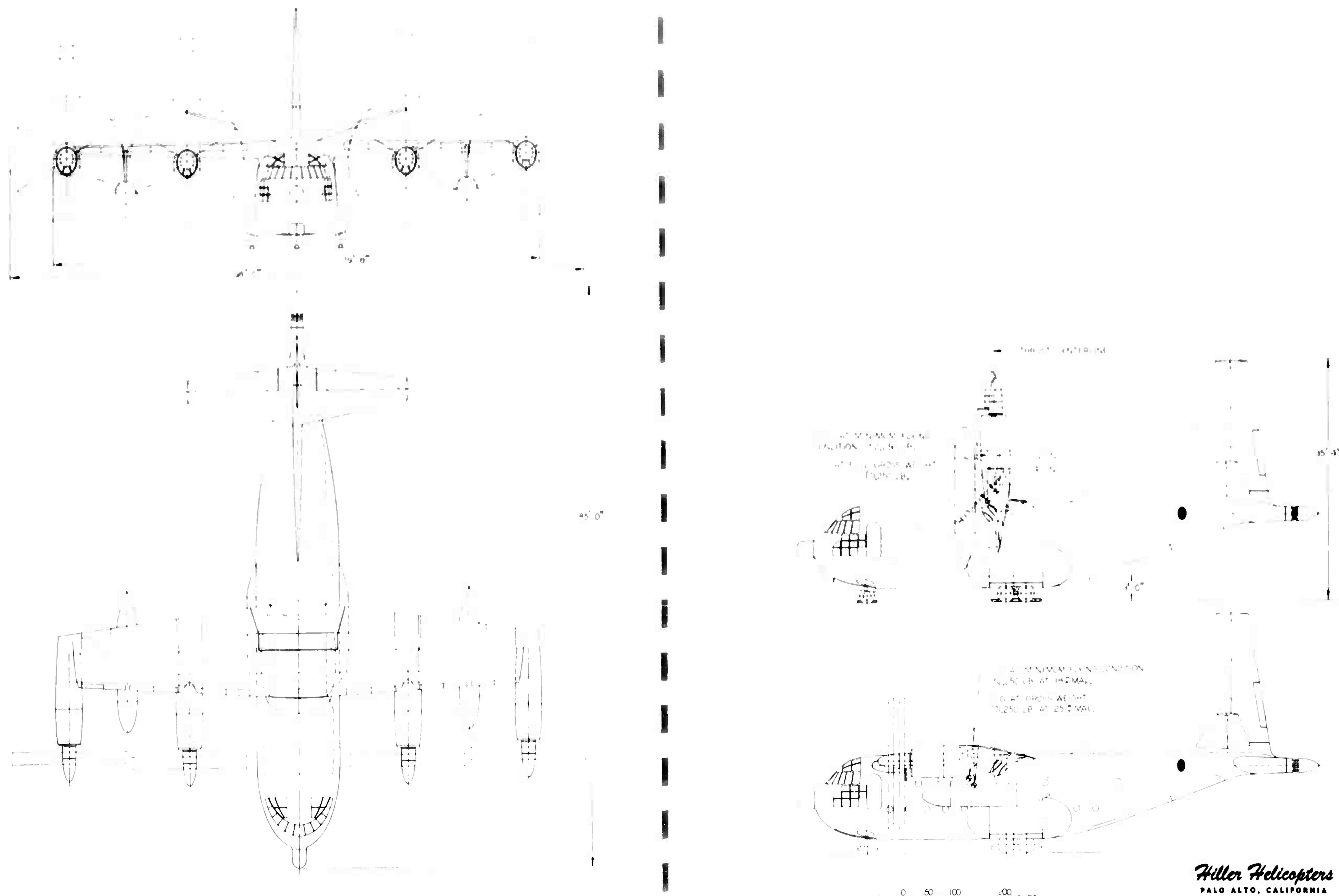

Hiller Helicopters
PALO ALTO, CALIFORNIA

GENERAL ARRANGEMENT			
SCALE NOTED	DRAWN HOBART / APP'VD	DATE 4-4-56 / DATE	DRAWING NO. 1048A-001

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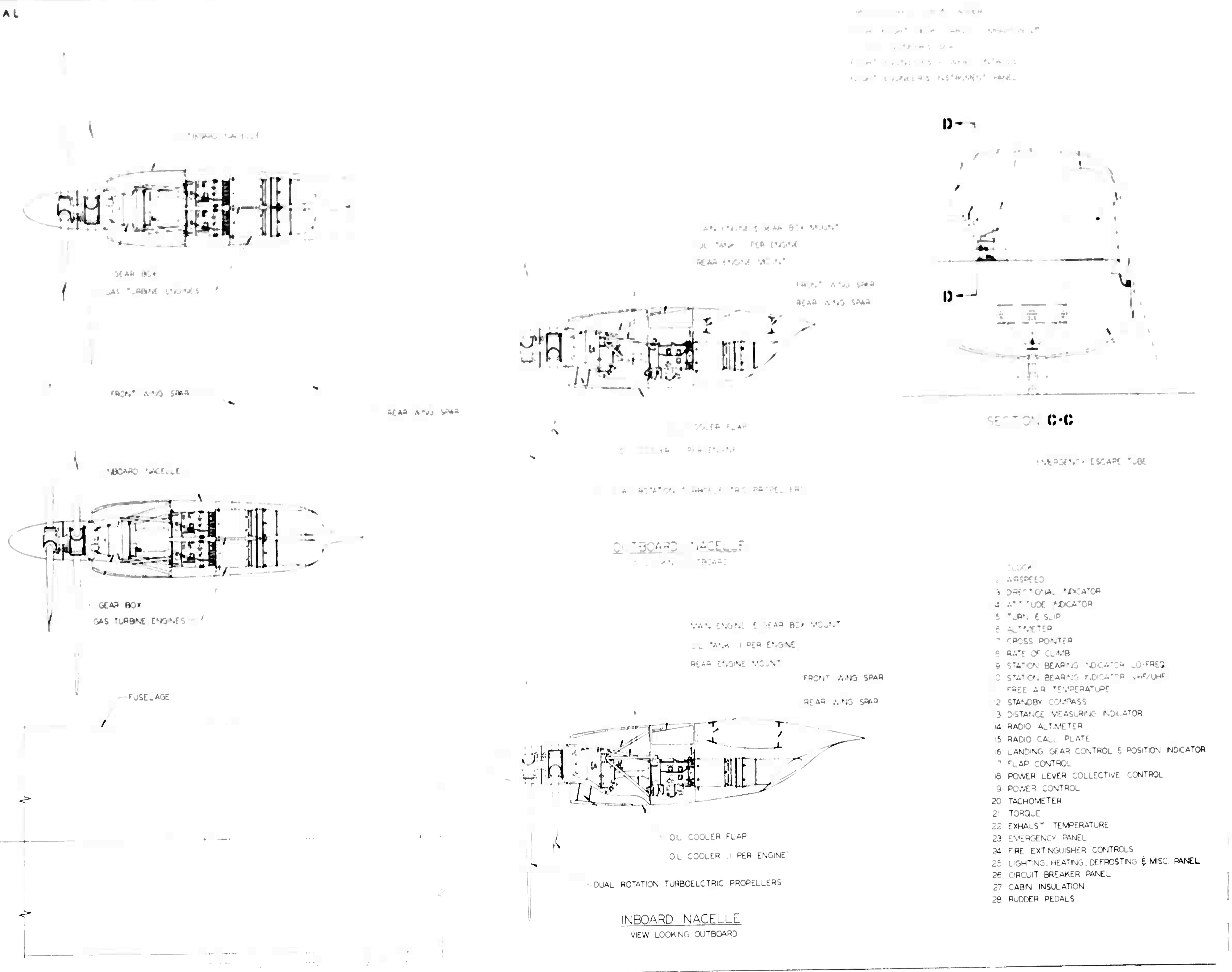
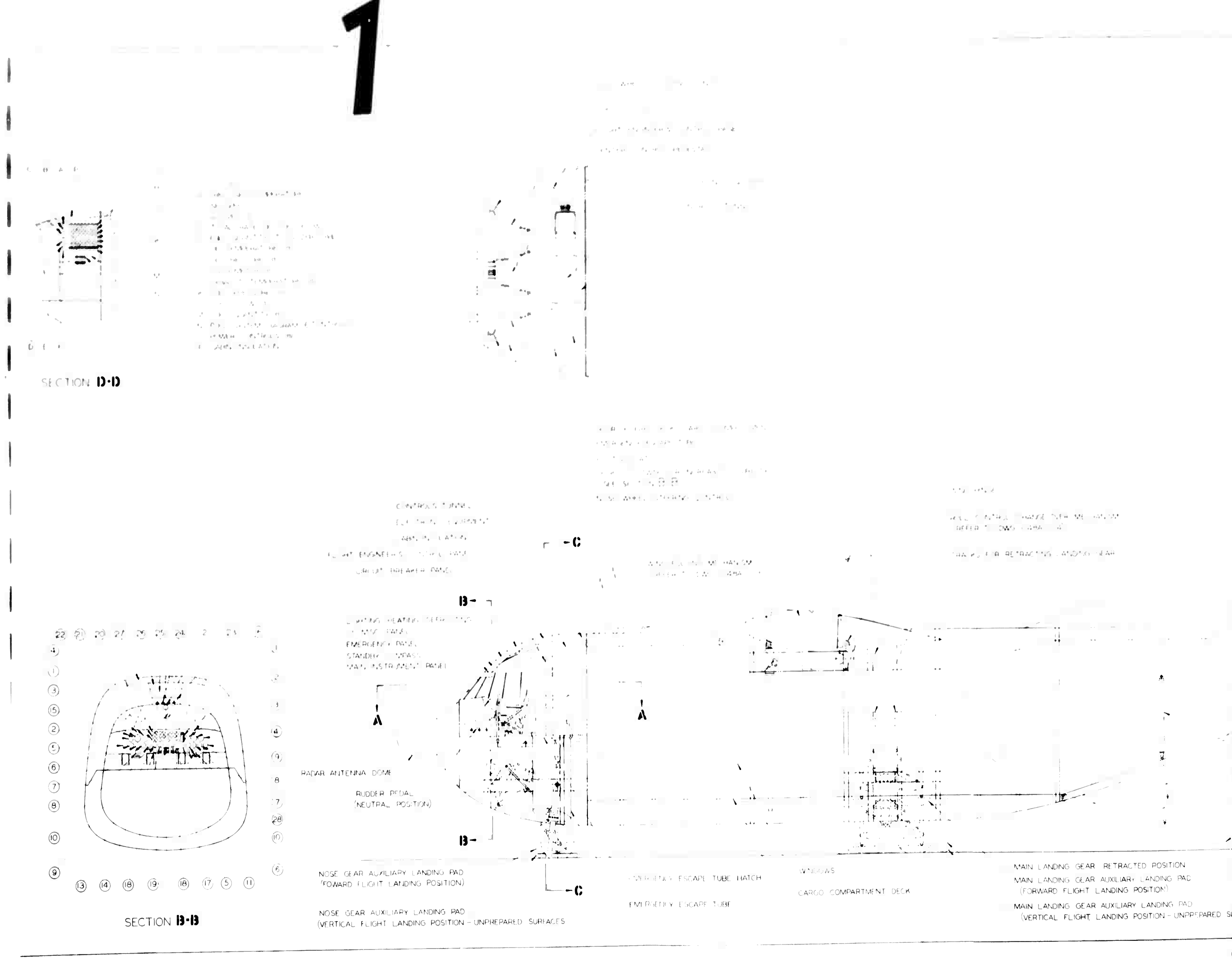
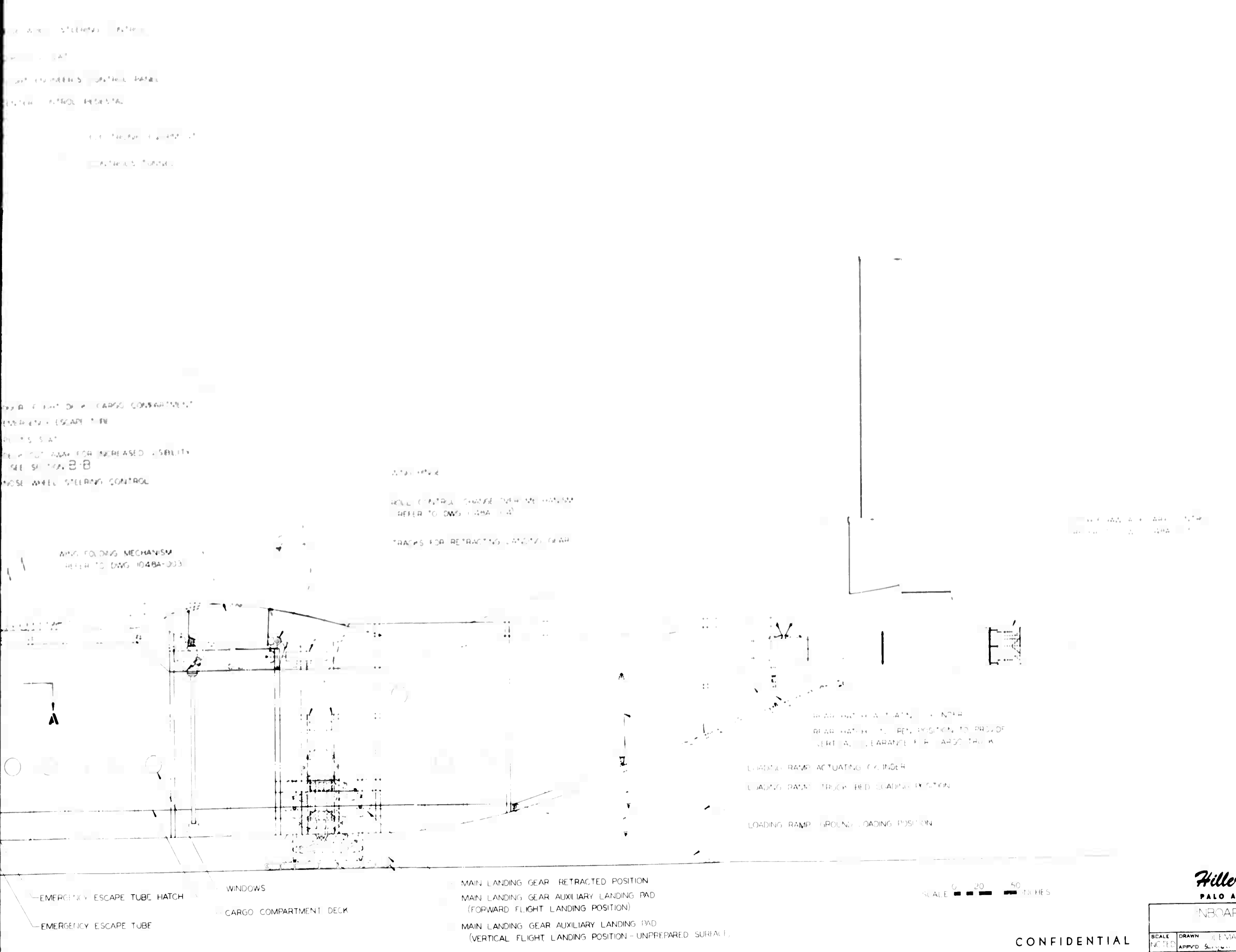



1
SECTION D-D
CONTROLS TUNNEL
RADAR ANTENNA DOME
RUDDER PEDAL
(NEUTRAL POSITION)
NOSE GEAR AUXILIARY LANDING PAD
(FOWARD FLIGHT LANDING POSITION)
NOSE GEAR AUXILIARY LANDING PAD
(VERTICAL FLIGHT LANDING POSITION - UNPREPARED SURFACES
EMERGENCY ESCAPE TUBE HATCH
EMERGENCY ESCAPE TUBE
WINDOWS
CARGO COMPARTMENT DECK
MAIN LANDING GEAR RETRACTED POSITION
MAIN LANDING GEAR AUXILIARY LANDING PAD
(FORWARD FLIGHT LANDING POSITION)
MAIN LANDING GEAR AUXILIARY LANDING PAD
(VERTICAL FLIGHT LANDING POSITION - UNPREPARED S
SECTION B-B



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INBOARD PROFILE

SCALE	DRAWN	DATE	DRAWING NO.
NOTED	APPV'D	DATE	1048A-002

2

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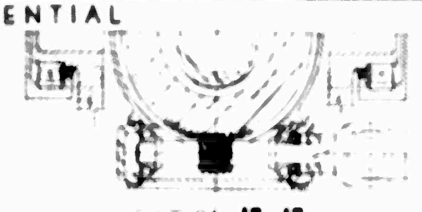
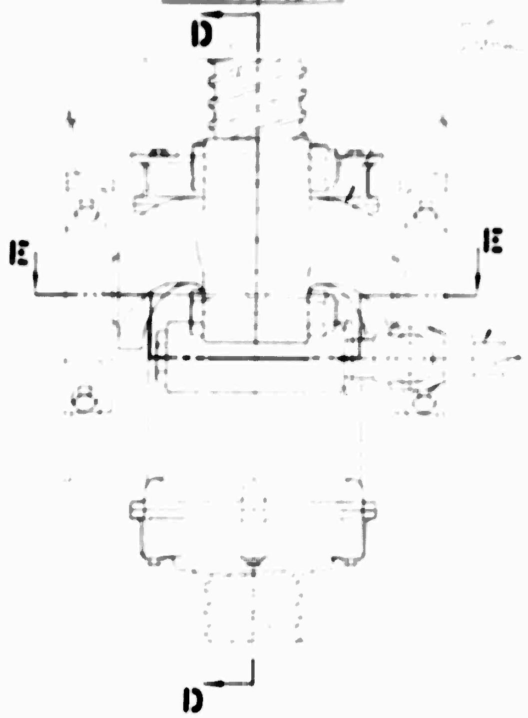


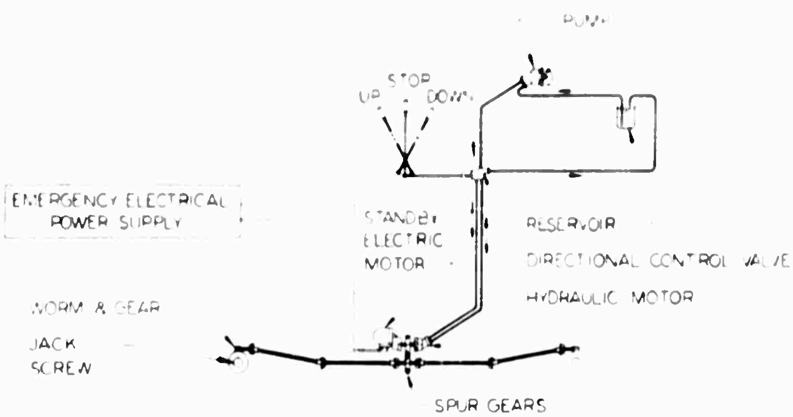
SECTION E-E



B-B

SCALE

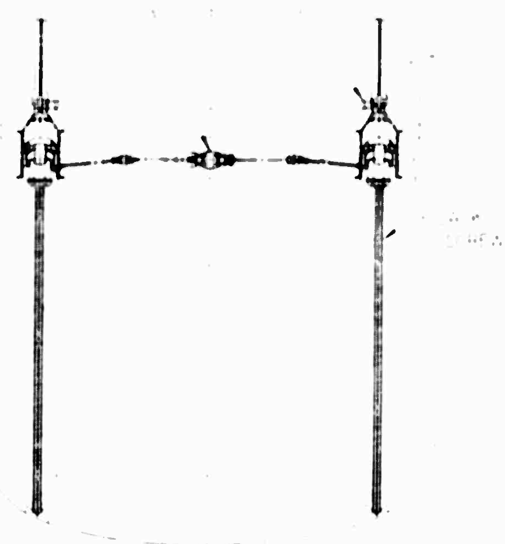
D-D



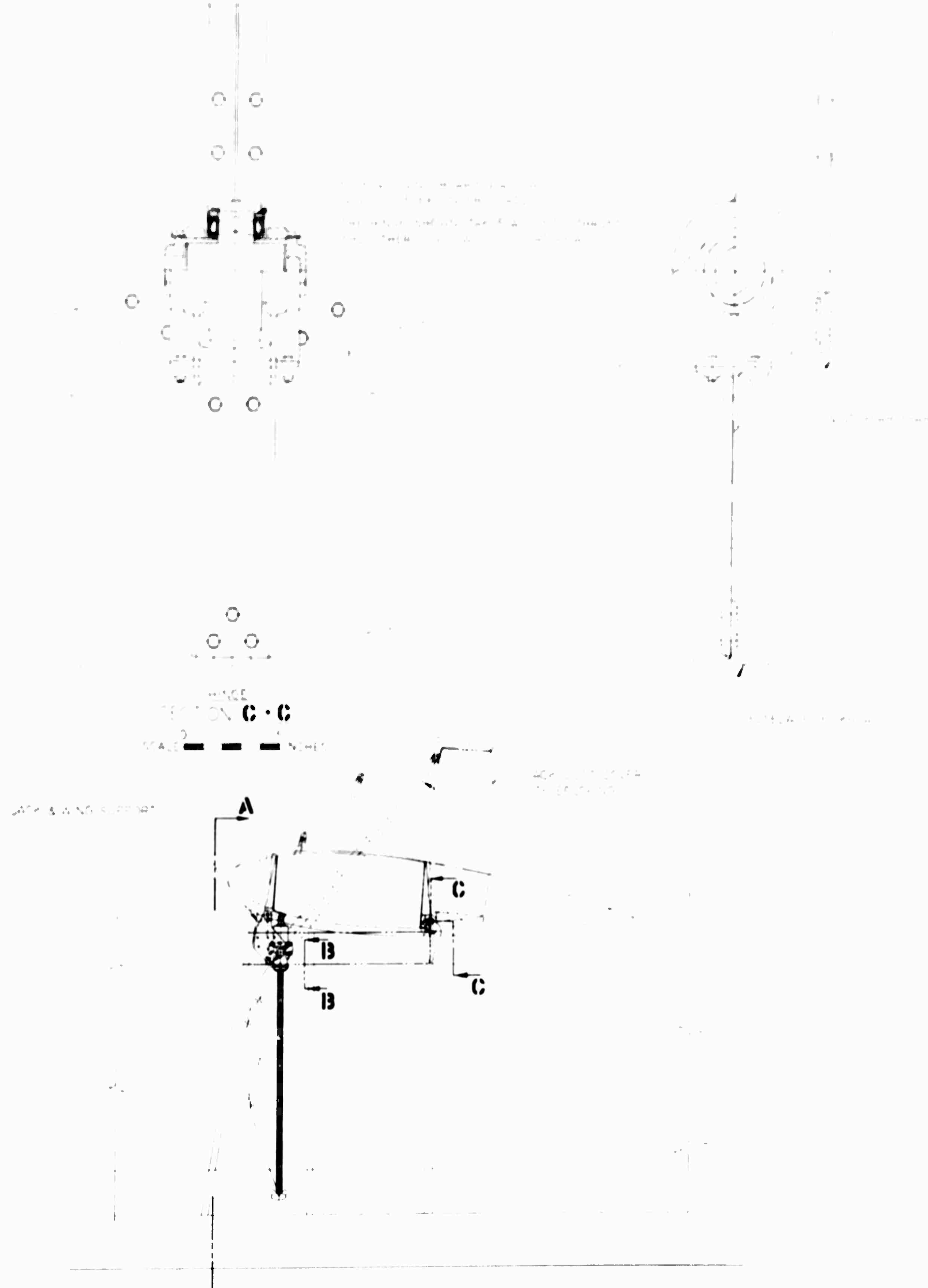
JACK ACTUATOR SYSTEM

(SCHEMATIC)

SCALE – NONE



VIEW A-A



SCALE 0 10 50 INCHES
EXCEPT AS NOTED

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WING HINGE AND ACTUATOR SYSTEM			
SCALE NOTED	DRAWN G. LARSON APPV'D	DATE 3/12/56 DATE	DRAWING NO. 1048A-003

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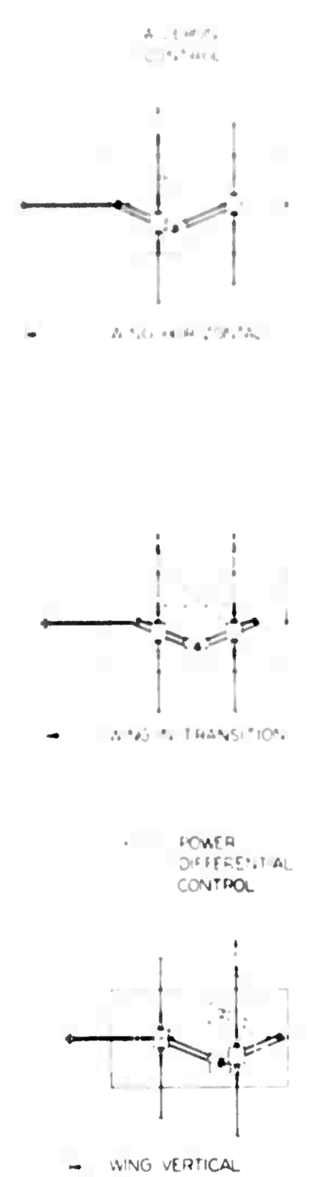
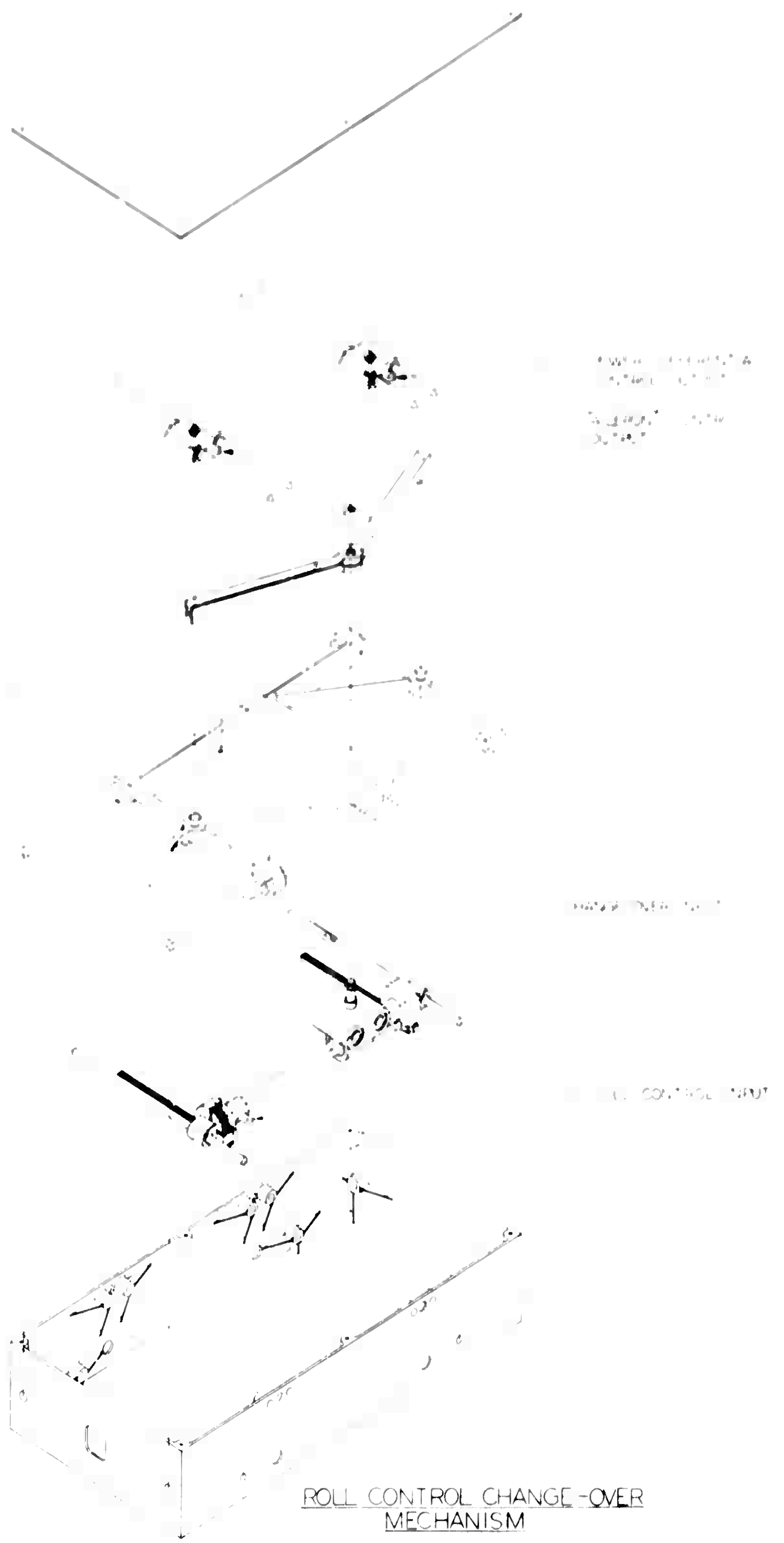
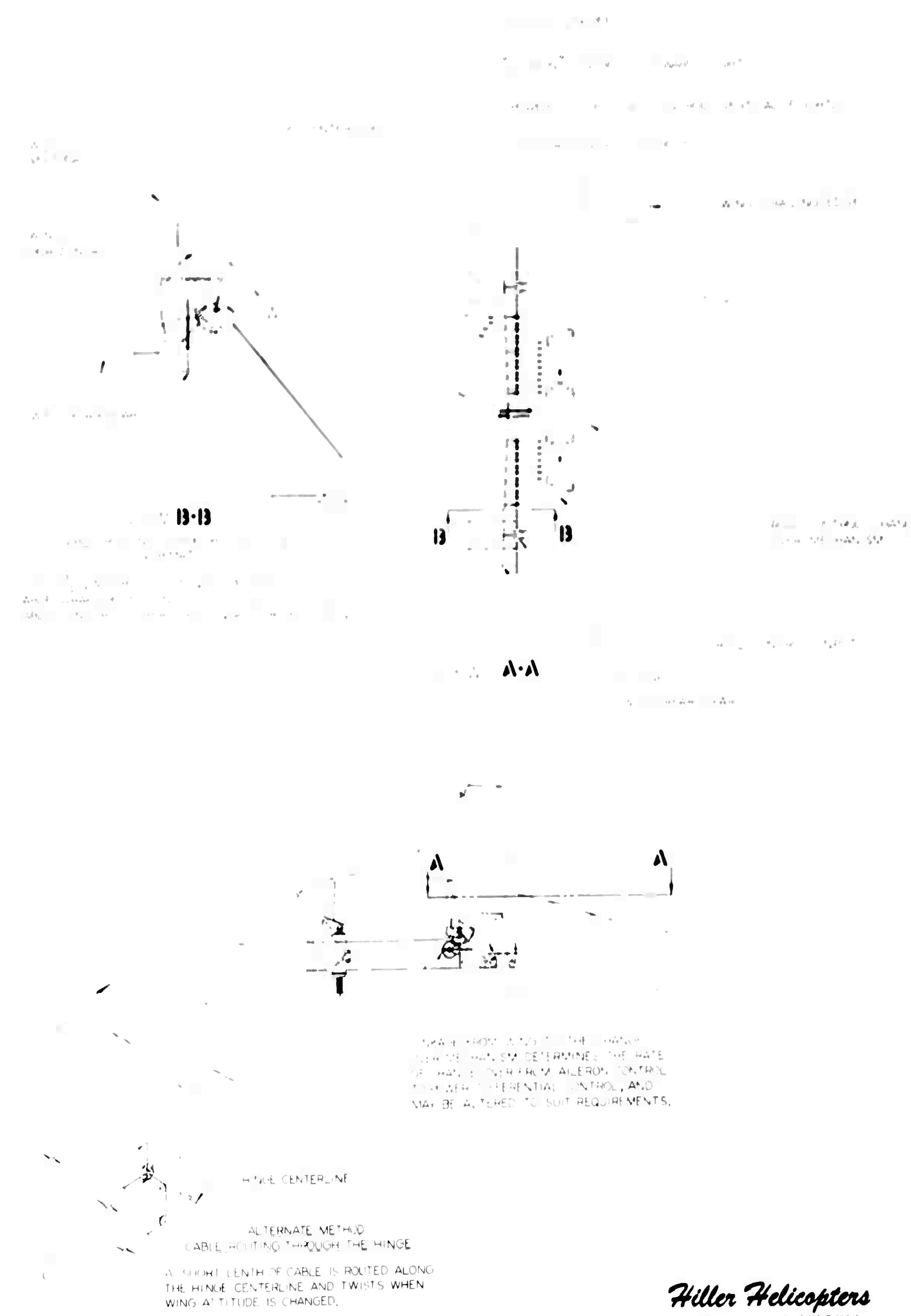


OPERATION OF THE CHANGE-OVER MECHANISM

WING ATTITUDE DETERMINES THE RATIO OF AILERON CONTROL TO POWER DIFFERENTIAL CONTROL



ROLL CONTROL CHANGE-OVER MECHANISM



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ROLL CONTROL SYSTEM			
SCALE NOTED	DRAWN G. LARSON	DATE 3/24/58	DRAWING NO. 1048A-004

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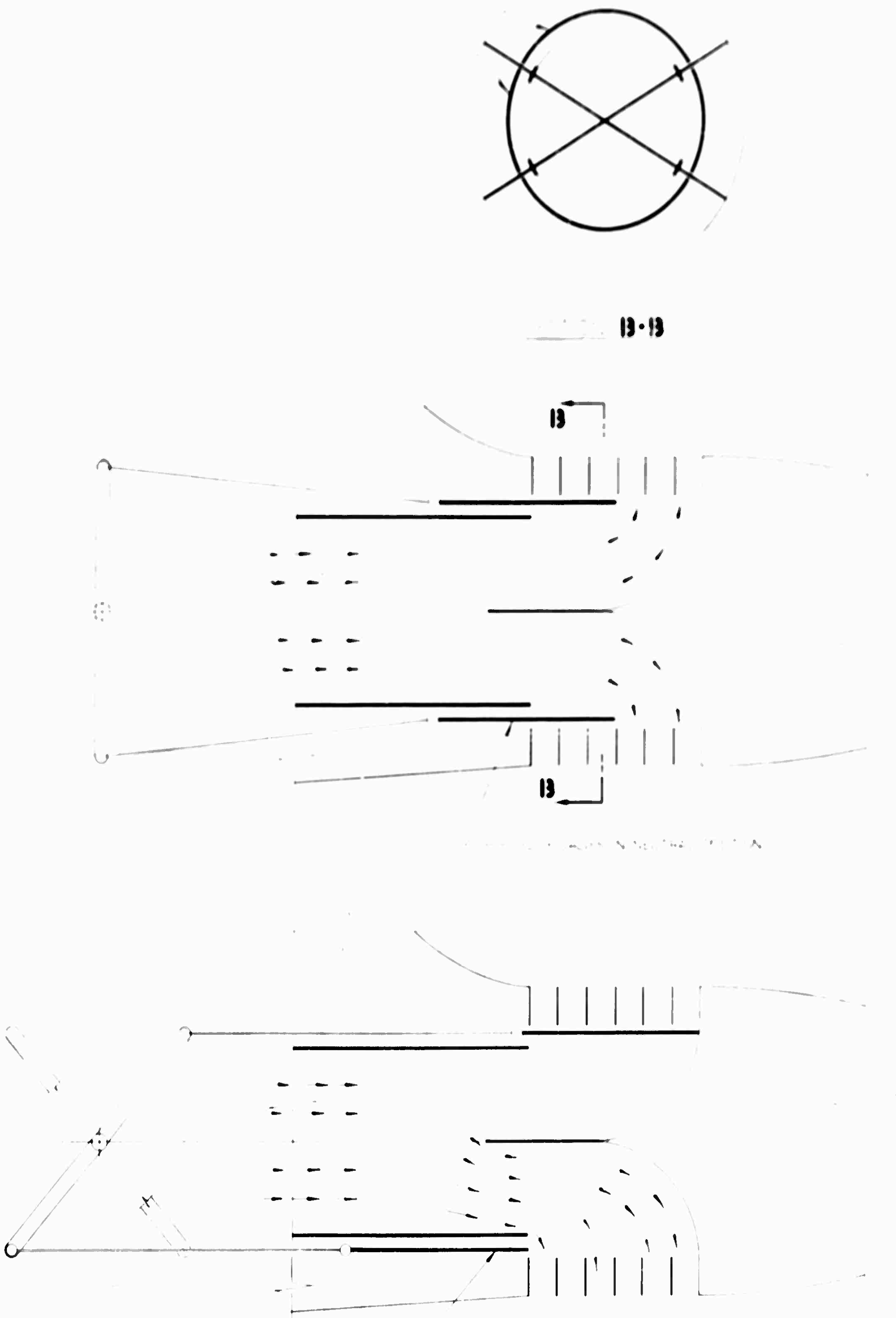
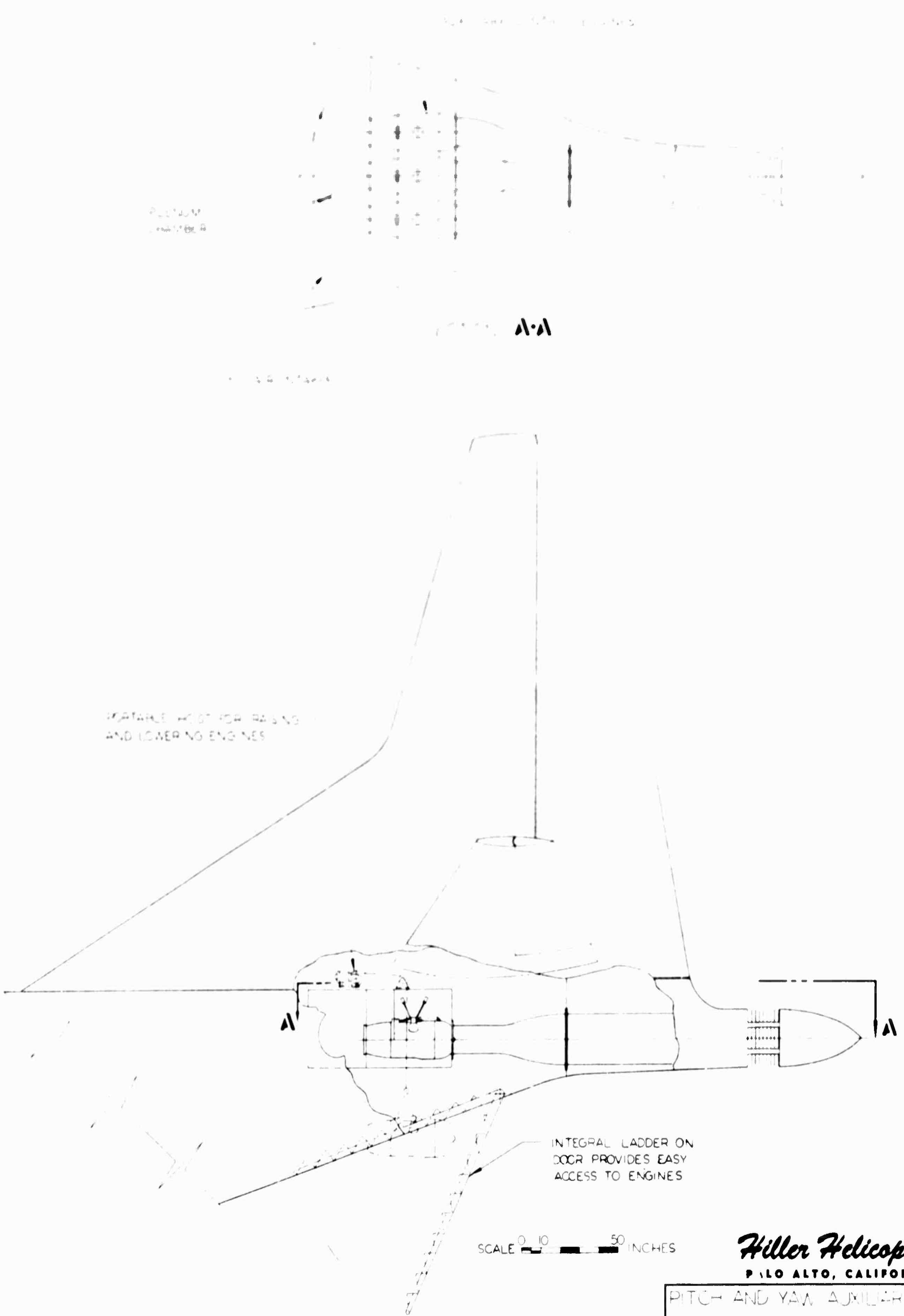


SLIDE VALVES IN POSITION FOR MAXIMUM
FORWARD PITCHING MOMENT

(YAW CONTROLS ARE SIMILAR TO PITCH CONTROLS)

CONTROL MECHANISM
SCHEMATIC



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PITCH AND YAW AUXILIARY CONTROL			
SCALE NOTED	DRAWN LITTLETON	DATE 3/23/56	DRAWING NO. 1048A-003
	APP'D	DATE	

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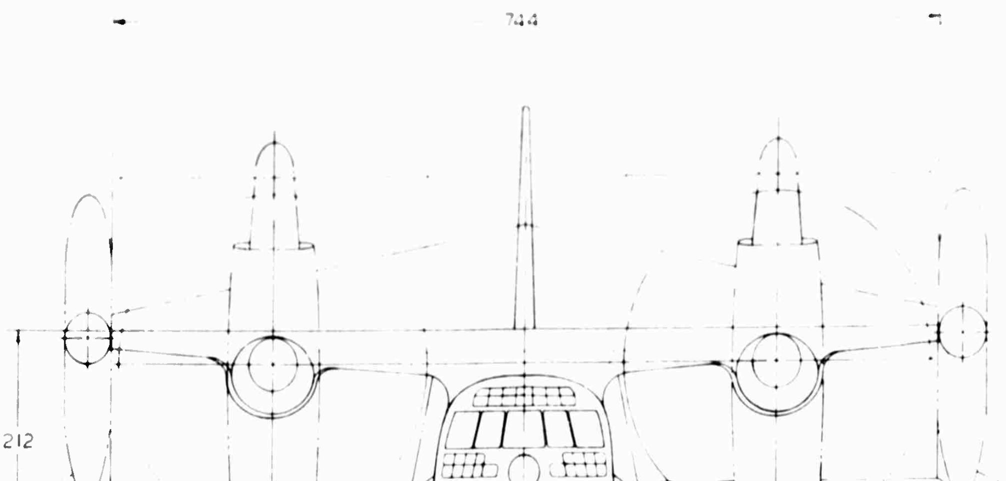

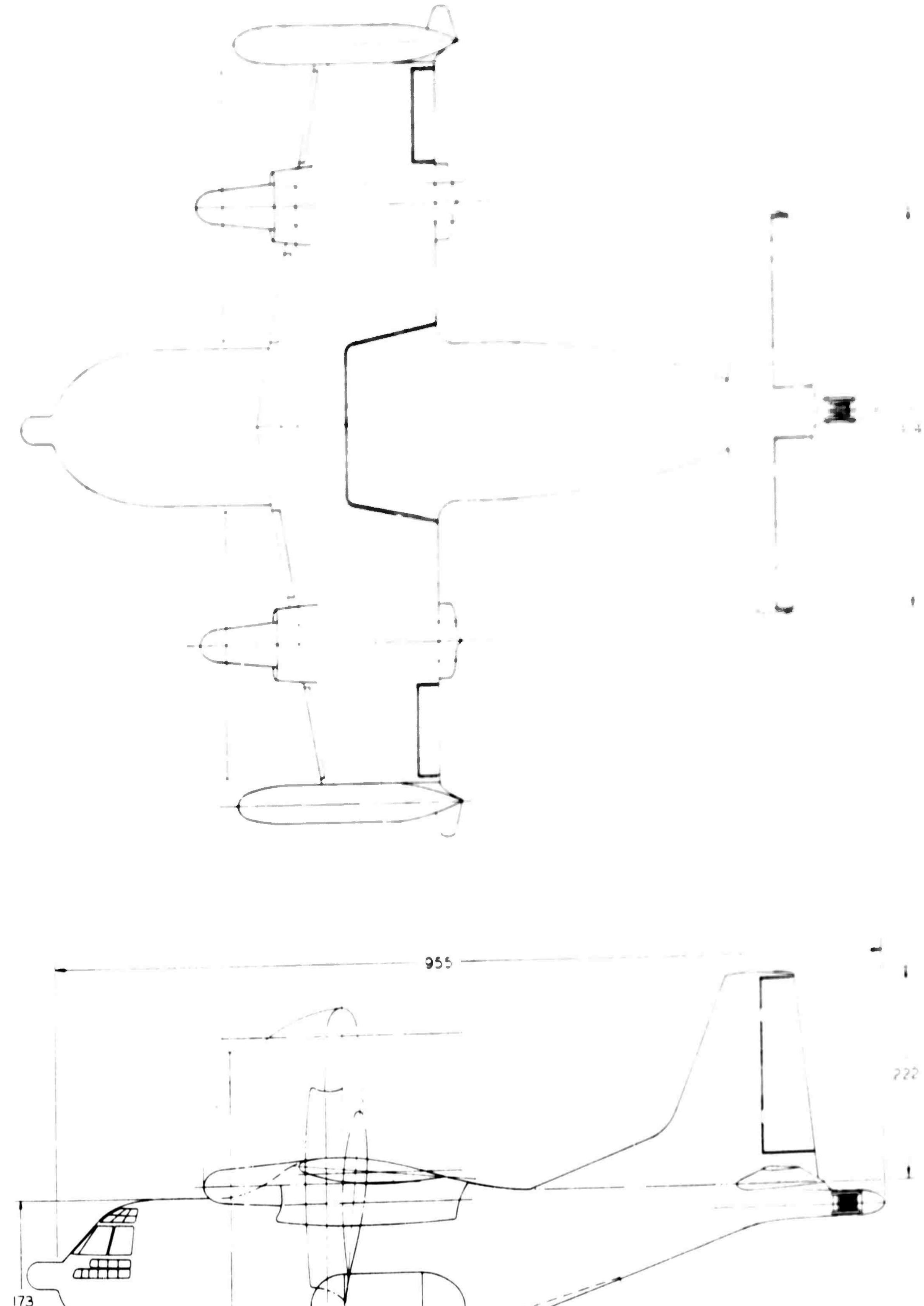

SCALE 0 50 100 200 INCHES

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PALO ALTO, CALIFORNIA

GENERAL ARRANGEMENT			
MODEL 1048 C		PROPELLOP	
SCALE NOTED	DRAWN LITTLETON APP'VD	DATE DATE	DRAWING NO. 1048C 00